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GREAT LAKES/ST. LAWRENCE SEAWAY REGIONAL TRANSPORTATION STUDY: --ETC(U)

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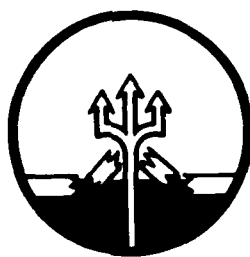
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Report 719C-2

UPDATE OF THE MAXIMUM SHIP SIZE STUDY
COSTS TO JANUARY 1981 DOLLARS

TASK 5.5 Report of Great Lakes/St. Lawrence
Seaway Regional Transportation Studies

Prime Contract DACW 35-80-C0060

September 1981

A. P. Free and L. A. Schultz

Submitted to

Department of the Army
North Central Division, Corps of Engineers
536 South Clark Street
Chicago, Illinois 60605

Submitted by

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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) | | |
| <p>This report has itemized the cost information from the draft "Maximum Ship Size" conducted in 1977 and updated those costs to January 1981 dollars. The costs are associated with a number of ship sizes and drafts and include improvement costs for channels, locks, harbors, bridges, and tunnels.</p> | | |

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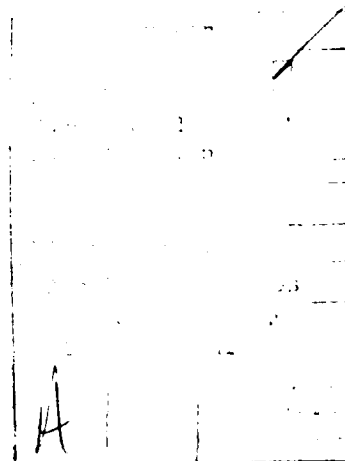
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UPDATE OF MAXIMUM SHIP SIZE STUDY
COSTS TO JANUARY 1981 DOLLARS

1. SUMMARY

The objective of this subtask is to show how the cost figures quoted in the "Maximum Ship Size Study" draft report [1] were obtained, and to update the costs to January 1981 dollars. The ship capital and operating costs, the required freight rates, and the Great Lakes/St. Lawrence Seaway structural and non-structural improvement costs from the "Maximum Ship Size Study" were separated into individual costs and are tabulated in this report. The costs were then updated to January 1981 dollars using general cost escalation figures obtained from *Engineering News Record* [2]. These general escalation figures cannot be applied to fuel cost increases, therefore the fuel cost portion of ship operating costs were updated using the actual fuel costs. A summary of the escalation factors used to update these costs is given in Table 1.

Required freight rates were used in the "Maximum Ship Size Study" as a measure of the benefits derived from modifying the Great Lakes/St. Lawrence Seaway System to handle larger ships than can currently pass through the system. A summary of the required freight rates escalated to January 1981 dollars for the ships and routes considered in the "Maximum Ship Size Study" is given in Tables 2A, 2B, and 3.

The costs of modifying the Great Lakes/St. Lawrence Seaway System to handle the larger ships must be considered to determine the optimal ship size. The cost of each required modification for each proposed ship size escalated to January 1981 dollars is given in Tables 4A through D.

TABLE 1 COST ESCALATION FACTORS

| DATE | BUILDING COST [2] INDEX | CONSTRUCTION COST [2] INDEX |
|----------------|----------------------------|--------------------------------|
| January 1981 | 2031 | 3400 |
| January 1977 | 1489 | 2494 |
| July 1977 | 1539 | 2579 |
| August 1977 | 1554 | 2611 |
| September 1977 | 1584 | 2644 |
| October 1977 | 1618 | 2675 |
| December 1977 | 1607 | 2669 |
| Base Year 1913 | 100 | 100 |

| DIESEL FUEL COST | JANUARY 1977 | JANUARY 1981 |
|------------------|----------------|----------------|
| Lake Ships | \$100/long ton | \$309/long ton |
| Ocean Ships | \$ 75/long ton | \$309/long ton |

Note:

The "Building Cost Index" is the price of a quantity of skilled labor and materials which cost \$100 in 1913.

The "Construction Cost Index" is the price of a quantity of common labor and materials which cost \$100 in 1913.

TABLE 2A UPDATED REQUIRED FREIGHT RATES OCEAN
SHIPS EUROPE TO GREAT LAKES

| VESSEL | GL PORT | YEAR-ROUND | | | 8.5 MO. WITH TRANSFER | | | 8.5 MO. WITH LAYOVER | | |
|--|------------|------------|-------|-------|-----------------------|-------|-------|----------------------|-------|-------|
| | | 25.5 | 28 | 32 | 36 | 25.5 | 28 | 32 | 36 | |
| <u>Container Ships¹ Route: Rotterdam-Montreal-Detroit-Chicago</u> | | | | | | | | | | |
| 730x75 | Mon. | 863 | 863 | 863 | NP | 867 | 867 | NP | 964 | 964 |
| | Det. | 1070 | 1040 | 1006 | NP | 1076 | 1045 | NP | 1200 | 1127 |
| | Chi. | 1283 | 1221 | 1152 | NP | 1289 | 1227 | NP | 1437 | 1291 |
| 940x105 | Mon. | 844 | 844 | 844 | 844 | 848 | 848 | 848 | 936 | 936 |
| | Det. | 1073 | 1034 | 997 | 983 | 1079 | 1039 | 988 | 1192 | 1106 |
| | Chi. | 1310 | 1231 | 1155 | 1127 | 1318 | 1237 | 1133 | 1455 | 1282 |
| <u>Bulk Carrier Route: Chicago-Baie Commeau-Rotterdam</u> | | | | | | | | | | |
| 730x75 | Chi. | 37.49 | 37.16 | 34.92 | NP | 37.49 | 37.16 | NP | 45.16 | 40.11 |
| | Bai | 27.87 | 26.52 | 24.92 | NP | 26.76 | 26.52 | NP | 32.23 | 29.97 |
| 1000x130 | Chi. | 22.53 | 22.39 | 21.10 | 19.82 | 22.63 | 22.43 | 19.78 | 27.34 | 23.91 |
| | Bai. | 16.09 | 15.96 | 15.01 | 14.10 | 15.15 | 16.00 | 7.26 | 19.52 | 17.00 |
| <u>General Cargo Ships Route: Rotterdam-Montreal-Detroit-Chicago</u> | | | | | | | | | | |
| 730x75 | Mon. | 19.64 | 19.16 | NP | NP | 19.68 | 19.20 | NP | 23.18 | 22.63 |
| | Det. | 23.00 | 22.34 | 21.19 | NP | 23.04 | 22.38 | NP | 27.14 | 26.36 |
| | Chi. | 26.34 | 25.58 | 24.27 | NP | 26.40 | 25.64 | NP | 31.09 | 30.19 |
| | | | | | | | | | 25.01 | 28.65 |

1. Container ship RFR's in \$/TEU; all others in \$/L.ton Jan. 1981 dollars.

NP denotes no plan in the "Maximum Ship Size Study".

TABLE 2B UPDATED REQUIRED FREIGHT RATES OCEAN
SHIPS JAPAN TO GREAT LAKES

| VESSEL | DEST. | YEAR-ROUND | | | 8.5 MO. WITH TRANSFER | | | 8.5 WITH LAYOVER | | |
|--|-------|------------|-------|-------|-----------------------|-------|-------|------------------|-------|--|
| | | 25.5 | 28 | 32 | 36 | 25.5 | 28 | 32 | 36 | |
| <u>Container Ships¹</u> <u>Route: Yokohama-Montreal-Detroit-Chicago</u> | | | | | | | | | | |
| 730x75 | Mon. | 1952 | NP | NP | NP | 1981 | NP | NP | NP | |
| | Det. | 2048 | NP | NP | NP | 2079 | NP | NP | NP | |
| | Chi. | 2146 | NP | NP | NP | 2179 | NP | NP | NP | |
| 940x105 | Mon. | 1827 | NP | NP | NP | 1846 | NP | NP | NP | |
| | Det. | 1917 | NP | NP | NP | 1937 | NP | NP | NP | |
| | Chi. | 2010 | NP | NP | NP | 2030 | NP | NP | NP | |
| <u>Bulk Carrier</u> <u>Route: Duluth-Baie Commeau-Japan</u> | | | | | | | | | | |
| 730x75 | Dul. | 89.21 | 88.46 | 87.12 | NP | 89.70 | 88.94 | 87.59 | NP | |
| | Bai. | 78.61 | 77.90 | 76.77 | NP | 79.04 | 78.32 | 77.18 | NP | |
| 1000x130 | Dul. | 51.50 | 51.16 | 50.42 | 49.68 | 51.96 | 51.52 | 50.72 | 49.88 | |
| | Bai. | 45.39 | 45.05 | 44.43 | 43.77 | 45.79 | 45.37 | 44.69 | 43.95 | |
| <u>General Cargo Ships</u> <u>Route: Japan-Montreal-Detroit-Chicago</u> | | | | | | | | | | |
| 730x75 | Mon. | 56.86 | 55.15 | NP | NP | 56.93 | 55.22 | NP | NP | |
| | Det. | 59.67 | 57.87 | 54.90 | NP | 59.74 | 57.94 | 54.97 | NP | |
| | Chi. | 62.51 | 60.64 | 57.49 | NP | 62.60 | 60.73 | 57.58 | NP | |
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1. Container ship RFR's in \$/TEU; all others in \$/L.ton Jan. 1981 dollars.

NP denotes no plan in the "Maximum Ship Size Study".

TABLE 3 UPDATED REQUIRED FREIGHT RATES (\$/L.TON)
GREAT LAKES BULK CARRIERS
ROUTE: DULUTH TO CHICAGO

| VESSEL SIZE | 8.5 MONTHS | | | 10 MONTHS | | | 12 MONTHS | | | | | |
|---------------|------------|------|------|-----------|-------|------|-----------|------|-------|------|------|------|
| | 25.5' | 28' | 32' | 36' | 25.5' | 28' | 32' | 36' | 25.5' | 28' | 32' | 36' |
| 1000x105x56 | 5.36 | 4.80 | 4.14 | NP | 5.02 | 4.50 | 3.87 | NP | 5.07 | 4.54 | 3.91 | NP |
| 1100x105x56 | 5.49 | 4.90 | 4.15 | NP | 5.16 | 4.59 | 3.89 | NP | 5.21 | 4.63 | 3.94 | NP |
| 1200x105x65 | 5.80 | 5.14 | 4.32 | NP | 5.45 | 4.83 | 4.06 | NP | 5.51 | 4.88 | 4.10 | NP |
| 1200x130x65 | 4.78 | 4.30 | 3.71 | NP | 4.52 | 4.07 | 3.50 | NP | 4.57 | 4.32 | 3.54 | NP |
| 1200x130x74 | 4.77 | 4.30 | 3.70 | 3.24 | 4.49 | 4.05 | 3.49 | 3.05 | 4.53 | 4.07 | 3.52 | 3.10 |
| 1200x175x65 | 4.83 | 4.27 | 3.91 | NP | 4.71 | 4.18 | 3.57 | NP | 4.75 | 4.23 | 3.61 | NP |
| 1200x175x74 | 4.95 | 4.37 | 3.73 | 3.28 | 4.66 | 4.19 | 3.53 | 3.36 | 4.68 | 4.16 | 3.59 | 3.15 |
| 1300x130x65 | 4.89 | 4.40 | 3.78 | NP | 4.62 | 4.14 | 3.86 | NP | 4.65 | 4.18 | 3.59 | NP |
| 1300x130x69.5 | 4.83 | 4.35 | 3.73 | NP | 4.56 | 4.11 | 3.51 | NP | 4.61 | 4.15 | 3.56 | NP |
| 1300x130x74 | 4.80 | 4.32 | 3.70 | 3.22 | 4.53 | 4.06 | 3.32 | 3.04 | 4.58 | 4.12 | 3.53 | 3.07 |
| 1300x175x65 | 4.79 | 4.24 | 3.63 | NP | 4.55 | 4.04 | 3.46 | NP | 4.60 | 4.09 | 3.50 | NP |
| 1300x175x69.5 | 4.74 | 4.21 | 3.59 | NP | 4.52 | 4.00 | 3.41 | NP | 4.57 | 4.06 | 3.47 | NP |
| 1300x175x74 | 4.74 | 4.21 | 3.59 | 3.16 | 4.52 | 3.99 | 3.41 | 3.00 | 4.57 | 4.05 | 3.46 | 3.05 |
| 1500x175x74 | 4.62 | 4.14 | 3.57 | 3.14 | 4.36 | 3.93 | 3.37 | 2.98 | 4.41 | 3.95 | 3.41 | 3.01 |

NP denotes no plan in the "Maximum Ship Size Study".

January 1981 dollars.

TABLE 4A STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$)
 JANUARY 1981 COSTS
 SHIP DRAFT = 25.5 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|-------------------------|---------|----------|----------|--------------|----------|----------|----------|
| Channel Dredging | | | | | | | |
| St. Marys River | 0 | 1,040 | 0 | 1,041 | 1,042 | 1,042 | 1,688 |
| Straits of Mackinac | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| St. Clair-Detroit-Pelee | 0 | 1,697 | 0 | 1,697 | 1,697 | 1,690 | 2,373 |
| Welland Canal | 1,343 | NP | 1,343 | NP | 1,620 | 1,620 | 2,319 |
| St. Lawrence | 2,894 | NP | 2,894 | NP | 3,790 | 3,790 | 6,020 |
| Total Channel | 4,237 | | 4,237 | | 8,149 | 8,142 | 12,400 |
| Compensating Struct. | | | | | | | |
| St. Marys River | | | | Not Required | | | |
| St. Clair River | | | | Not Required | | | |
| Detroit River | | | | Not Required | | | |
| Total Comp. Struct. | | | | | | | |
| Locks | | | | | | | |
| Soo | 74 | No Plan | 87 | No Plan | 100 | 101 | 118 |
| St. Clair | 0 | | 65 | | 75 | 80 | 94 |
| Welland Canal | 631 | | 738 | | 836 | 892 | 1,015 |
| St. Lawrence | 531 | | 621 | | 706 | 751 | 867 |
| Total Locks | 1,291 | | 1,511 | | 1,717 | 1,824 | 2,094 |

TABLE 4A STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$) (CONTINUED)

JANUARY 1981 COSTS

SHIP DRAFT = 25.5 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|----------------------------|---------|----------|----------|----------|----------|----------|----------|
| Harbor Dredging | | | | | | | |
| Ashtabula | NP | No Plan | 3 | No Plan | 5 | 6 | 6 |
| Buffalo | 26 | | 27 | | 30 | 31 | 32 |
| Burns Harbor | 2 | | 0 | | 8 | 9 | 9 |
| Calumet | 0 | | 0 | | 23 | 25 | 34 |
| Cleveland | 1 | | 12 | | 13 | 13 | 13 |
| Conneaut | NP | | 3 | | 4 | 5 | 5 |
| Detroit | 0 | | 97 | | 12 | 13 | 15 |
| Duluth-Superior | 0 | | 0 | | 108 | 118 | 123 |
| Gary | NP | | 0 | | 7 | 7 | 7 |
| Indiana | NP | | 0 | | 13 | 14 | 19 |
| Lorain | NP | | 11 | | 18 | 24 | 24 |
| Milwaukee | 8 | | NP | | NP | NP | NP |
| Presque Isle | NP | | 0 | | 1 | 1 | 1 |
| Sandusky | NP | | 104 | | 119 | 134 | 134 |
| Toledo | 170 | | 0 | | 161 | 196 | 196 |
| Two Harbors | NP | | 0 | | 5 | 6 | 6 |
| Total Harbors | 207 | | 257 | | 527 | 602 | 624 |
| Bridges and Tunnels | | | | | | | |
| Construction Capital Costs | 109 | 133 | 109 | 133 | 133 | 133 | 194 |
| Aids to Navigation | 5,789 | | 6,114 | | 10,526 | 10,701 | 15,312 |
| Real Estate | 58 | | 61 | | 105 | 107 | 153 |
| Contingency | 116 | | 122 | | 211 | 214 | 306 |
| E&D and S&A | 1,193 | | 1,259 | | 2,168 | 2,204 | 3,154 |
| Non-Fed First Costs | 809 | | 854 | | 1,471 | 1,494 | 2,138 |
| Investment Costs | 159 | | 168 | | 290 | 294 | 412 |
| | 2,996 | | 3,164 | | 5,446 | 5,537 | 7,923 |
| GRAND TOTAL | 11,119 | | 11,743 | | 20,216 | 20,552 | 29,408 |

NP denotes no plan in the "Maximum Ship Size Study".

TABLE 4B STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$)
JANUARY 1981 COSTS
SHIP DRAFT = 28 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|-------------------------|---------|----------|----------|----------|----------|----------|----------|
| Channel Dredging | | | | | | | |
| St. Marys River | 546 | 1,296 | 546 | 1,304 | 1,312 | 1,312 | 1,975 |
| Straits of Mackinac | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| St. Clair-Detroit-Pelee | 1,515 | 1,562 | 1,515 | 1,735 | 1,928 | 1,921 | 2,678 |
| Welland Canal | 1,490 | NP | 1,490 | NP | 1,809 | 1,809 | 2,523 |
| St. Lawrence | 3,751 | NP | 3,751 | NP | 4,798 | 4,798 | 7,348 |
| Total Channel | 7,307 | | 7,307 | | 9,852 | 9,845 | 14,584 |
| Compensating Struct. | | | | | | | |
| St. Marys River | 129 | 129 | 129 | 129 | 129 | 129 | 219 |
| St. Clair River | 114 | 114 | 114 | 114 | 114 | 114 | 114 |
| Detroit River | 193 | 193 | 193 | 193 | 193 | 193 | 193 |
| Total Comp. Struct. | 436 | 436 | 436 | 436 | 436 | 436 | 436 |
| Locks | | | | | | | |
| Soo | 82 | No Plan | 96 | No Plan | 107 | 117 | 137 |
| St. Clair | 63 | | 74 | | 85 | 89 | 105 |
| Welland Canal | 692 | | 810 | | 913 | 971 | 1,105 |
| St. Lawrence | 580 | | 679 | | 775 | 824 | 952 |
| Total Locks | 1,417 | | 1,659 | | 1,880 | 2,001 | 2,299 |

TABLE 4B STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$) (CONTINUED)
JANUARY 1981 COSTS
SHIP DRAFT = 28 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|----------------------------|---------|----------|----------|----------|----------|----------|----------|
| Harbor Dredging | | | | | | | |
| Ashtabula | NP | No Plan | 8 | No Plan | 13 | 12 | 12 |
| Buffalo | 42 | | 48 | | 49 | 49 | 51 |
| Burns Harbor | 4 | | 2 | | 2 | 3 | 3 |
| Calumet | 70 | | 81 | | 110 | 119 | 160 |
| Cleveland | 5 | | 17 | | 19 | 20 | 20 |
| Conneaut | NP | | 5 | | 7 | 9 | 9 |
| Detroit | 2 | | 134 | | 18 | 18 | 21 |
| Duluth-Superior | 49 | | 122 | | 140 | 155 | 161 |
| Gary | NP | | 12 | | 12 | 11 | 11 |
| Indiana | NP | | 53 | | 32 | 35 | 47 |
| Lorain | NP | | 19 | | 29 | 39 | 39 |
| Milwaukee | 14 | | NP | | NP | NP | NP |
| Presque Isle | NP | | 2 | | 2 | 2 | 2 |
| Sandusky | NP | | 152 | | 173 | 193 | 194 |
| Toledo | 212 | | 165 | | 204 | 243 | 243 |
| Two Harbors | NP | | 8 | | 9 | 10 | 10 |
| Total Harbors | 398 | | 828 | | 919 | 918 | 183 |
| Bridges & Tunnels | 114 | | 114 | | 141 | 141 | 202 |
| Construction Capital Costs | 9,672 | 141 | 11,859 | 141 | 13,228 | 13,341 | 18,504 |
| Aids to Navigation | 97 | | 119 | | 132 | 133 | 185 |
| Real Estate | 193 | | 237 | | 265 | 267 | 370 |
| Contingency | 1,992 | | 2,443 | | 2,725 | 2,748 | 3,812 |
| E&D and S&A | 1,351 | | 1,656 | | 1,848 | 1,863 | 2,584 |
| Non-Fed First Costs | 266 | | 326 | | 364 | 367 | 509 |
| Investment Costs | 5,005 | | 6,136 | | 6,844 | 6,903 | 9,574 |
| GRAND TOTAL | 18,576 | | 22,776 | | 25,406 | 25,623 | 35,539 |

NP denotes no plan in the "Maximum Ship Size Study".

TABLE 4C STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$)
 JANUARY 1981 COSTS
 SHIP DRAFT = 32 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|-------------------------|---------|----------|----------|----------|----------|----------|----------|
| Channel Dredging | | | | | | | |
| St. Marys River | 1,103 | 2,087 | 1,103 | 2,094 | 2,101 | 2,101 | 2,907 |
| Straits of Mackinac | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| St. Clair-Detroit-Pelee | 8,319 | 8,531 | 8,319 | 8,742 | 8,953 | 8,782 | 10,083 |
| Welland Canal | 1,735 | NP | 1,735 | NP | 2,105 | 2,105 | 2,935 |
| St. Lawrence | 5,205 | NP | 5,205 | NP | 6,515 | 6,515 | 9,606 |
| Total Channel | 16,395 | | 16,395 | | 19,707 | 19,536 | 25,564 |
| Compensating Struct. | | | | | | | |
| St. Marys River | 141 | 141 | 141 | 141 | 141 | 141 | 141 |
| St. Clair River | 191 | 191 | 191 | 191 | 191 | 191 | 191 |
| Detroit River | 215 | 215 | 215 | 215 | 215 | 215 | 215 |
| Total Comp. Struct. | 547 | 547 | 547 | 574 | 547 | 547 | 547 |
| Locks | | | | | | | |
| Soo | 88 | No Plan | 103 | No Plan | 119 | 126 | 145 |
| St. Clair | 68 | | 80 | | 92 | 98 | 115 |
| Welland Canal | 734 | | 859 | | 966 | 1,030 | 1,170 |
| St. Lawrence | 621 | | 727 | | 827 | 877 | 1,015 |
| Total Locks | 1,511 | | 1,769 | | 2,004 | 2,131 | 2,445 |

TABLE 4C STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$) (CONTINUED)
JANUARY 1981 COSTS
SHIP DRAFT = 32 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|----------------------------|---------|----------|----------|----------|----------|----------|----------|
| Harbor Dredging | | | | | | | |
| Ashtabula | NP | No Plan | 18 | No Plan | 22 | 26 | 26 |
| Buffalo | 105 | | 120 | | 122 | 123 | 129 |
| Burns Harbor | 9 | | 5 | | 5 | 5 | 5 |
| Calumet | 157 | | 184 | | 249 | 270 | 363 |
| Cleveland | 16 | | 36 | | 38 | 39 | 40 |
| Conneaut | NP | | 17 | | 20 | 22 | 22 |
| Detroit | 5 | | 210 | | 27 | 28 | 30 |
| Duluth-Superior | 75 | | 180 | | 200 | 218 | 224 |
| Gary | NP | | 30 | | 28 | 26 | 26 |
| Indiana | NP | | 125 | | 82 | 89 | 120 |
| Lorain | NP | | 35 | | 49 | 62 | 64 |
| Milwaukee | 24 | | NP | | NP | NP | NP |
| Presque Isle | NP | | 8 | | 9 | 10 | 10 |
| Sandusky | NP | | 235 | | 266 | 294 | 298 |
| Toledo | 316 | | 269 | | 322 | 376 | 376 |
| Two Harbors | NP | | 18 | | 21 | 24 | 24 |
| Total Harbors | 707 | | 1,490 | | 1,459 | 1,612 | 1,756 |
| Bridges & Tunnels | | | | | | | |
| Construction Capital Costs | 121 | 150 | 121 | 150 | 150 | 150 | 213 |
| Aids to Navigation | 19,281 | | 20,322 | | 23,867 | 23,976 | 30,525 |
| Real Estate | 193 | | 203 | | 239 | 240 | 305 |
| Contingency | 386 | | 406 | | 477 | 480 | 611 |
| E&D and S&A | 3,972 | | 4,186 | | 4,917 | 4,939 | 6,288 |
| Non-Fed First Costs | 2,693 | | 2,838 | | 3,333 | 3,349 | 4,263 |
| Investment Costs | 530 | | 559 | | 657 | 660 | 840 |
| | 9,976 | | 10,515 | | 12,349 | 12,406 | 15,794 |
| GRAND TOTAL | 37,031 | | 39,031 | | 45,839 | 46,048 | 58,626 |

NP denotes no plan in the "Maximum Ship Size Study".

TABLE 4D STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$)
JANUARY 1981 COSTS
SHIP DRAFT = 36 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|-------------------------|---------|----------|----------|----------|----------|----------|----------|
| Channel Dredging | | | | | | | |
| St. Marys River | 1,517 | 2,872 | No Plan | 2,881 | 2,889 | 2,889 | 2,864 |
| Straits of Mackinac | 69 | 69 | | 69 | 69 | 69 | 71 |
| St. Clair-Detroit-Pelee | 14,638 | 14,998 | | 15,357 | 15,717 | 15,649 | 17,165 |
| Welland Canal | 2,007 | NP | | NP | 2,434 | 2,434 | 3,397 |
| St. Lawrence | 6,695 | NP | | NP | 8,379 | 8,379 | 12,136 |
| Total Channel | 24,926 | | | | 29,488 | 29,420 | 35,633 |
| Compensating Struct. | | | | | | | |
| St. Marys River | 154 | 154 | | 154 | 154 | 154 | 154 |
| St. Clair River | 216 | 216 | | 216 | 216 | 216 | 216 |
| Detroit River | 245 | 245 | | 245 | 245 | 245 | 245 |
| Total Comp. Struct. | 615 | 615 | | 615 | 615 | 615 | 615 |
| Locks | | | | | | | |
| Soo | 104 | No Plan | | No Plan | 139 | 141 | 173 |
| St. Clair | 82 | | | | 111 | 117 | 128 |
| Welland Canal | 813 | | | | 1,074 | 1,141 | 1,300 |
| St. Lawrence | 703 | | | | 928 | 989 | 1,116 |
| Total Locks | 1,702 | | | | 2,252 | 2,388 | 2,717 |

TABLE 4D STRUCTURAL AND NON-STRUCTURAL COSTS SUMMARY (MILLION \$) (CONTINUED)
 JANUARY 1981 COSTS
 SHIP DRAFT = 36 FT

| PLAN COMPONENT | 940x105 | 1000x130 | 1100x105 | 1100x130 | 1200x130 | 1300x130 | 1300x175 |
|----------------------------|---------|----------|----------|----------|----------|----------|----------|
| Harbor Dredging | | | | | | | |
| Ashtabula | NP | No Plan | No Plan | No Plan | 48 | 51 | 55 |
| Buffalo | 157 | | | | 241 | 252 | 277 |
| Burns Harbor | 14 | | | | 8 | 8 | 8 |
| Calumet | 242 | | | | 382 | 414 | 557 |
| Cleveland | 27 | | | | 58 | 60 | 62 |
| Conneaut | NP | | | | 37 | 40 | 43 |
| Detroit | 6 | | | | 35 | 37 | 39 |
| Duluth-Superior | 101 | | | | 265 | 286 | 297 |
| Gary | NP | | | | 64 | 63 | 63 |
| Indiana | NP | | | | 181 | 196 | 264 |
| Lorain | NP | | | | 87 | 109 | 114 |
| Milwaukee | 33 | | | | NP | NP | NP |
| Presque Isle | NP | | | | 20 | 22 | 22 |
| Sandusky | NP | | | | 453 | 493 | 512 |
| Toledo | 751 | | | | 758 | 857 | 857 |
| Two Harbors | NP | | | | 38 | 41 | 41 |
| Total Harbors | 1,331 | | | | 2,675 | 2,929 | 3,211 |
| Bridges & Tunnels | | | | | | | |
| Construction Capital Costs | 128 | 158 | | 158 | 158 | 158 | 225 |
| Aids to Navigation | 28,574 | | | | 35,030 | 35,352 | 42,176 |
| Real Estate | 286 | | | | 350 | 354 | 422 |
| Contingency | 571 | | | | 701 | 707 | 844 |
| E&D and S&A | 5,886 | | | | 7,216 | 7,283 | 8,688 |
| Non-Fed First Costs | 3,991 | | | | 4,893 | 4,938 | 5,891 |
| Investment Costs | 786 | | | | 964 | 973 | 1,160 |
| | 14,785 | | | | 18,125 | 18,292 | 21,823 |
| GRAND TOTAL | 54,879 | | | | 67,279 | 67,897 | 81,003 |

NP denotes no plan in the "Maximum Ship Size Study".

2. INTRODUCTION

The Great Lakes/St. Lawrence Seaway System (GL/SLS) provides deep water access from the Atlantic Ocean to ports in a 19 state region extending approximately 2400 miles inland [3]. In order to maximize the national benefits from the use of the GL/SLS System, the largest ship which is economically feasible to operate on the system must be identified. This will allow for proper long range planning of the System.

The current limitations on ship size in the GL/SLS System exist because of the sizes of the locks, channels, and harbors. Ships are generally assumed to have positive economics of scale. Therefore, the maximum ship size which is economically feasible becomes a trade-off between the increasing benefits of building and operating larger ships, and the increasing costs of improving the system to handle those larger ships.

The U.S. Army Corps of Engineers North Central Division performed a study to determine the largest economical ship size for the GL/SLS System. This study, entitled "Maximum Ship Size Study" [1], was published in draft form in December 1977.

The purposes of this report are to document the cost components of the "Maximum Ship Size Study" and to update all of the Study costs to January 1981 dollars. Each GL/SLS System structural and non-structural improvement cost was investigated to determine how it was obtained. These improvement costs are itemized by ship size and draft for each channel, lock, harbor, bridge, and tunnel requiring modification. In addition, total system improvement estimates were made based on ship size and draft for aids to navigation, real estate, contingencies, engineering and design, supervision and administration, non-federal first costs, investment costs, and operational maintenance costs.

The costs were updated to January 1981 dollars using appropriate escalation factors. In most cases the escalation factors were the "Building Cost Index" and the "Construction Cost Index" prepared by *Engineering News Record*. Ship capital and operating costs and the required freight rates (RFR) for the example routes used in the "Maximum Ship Size Study" were also updated to January 1981 dollars.

In order to obtain the individual ship costs, required freight rates, and system improvement costs from the "Maximum Ship Size Study", the unpublished appendices to the "Maximum Ship Size Study", the working notes developed during the course of the study, and the work of outside consultants called upon during the study were reviewed. All reference material used in preparing this update is documented in Section 6 of this report.

3. VESSEL COST DATA

Fourteen prototype lake bulk carriers and five prototype oceangoing ships, consisting of two container ships, two bulk carriers, and one general cargo ship, were treated in the "Maximum Ship Size Study" as possible ships for operation on the Great Lakes/St. Lawrence Seaway System. The ships were analyzed at a series of drafts ranging from 25.5 to 36 ft. A basic assumption of the 1977 "Maximum Ship Size Study" was that all of these ships would be U.S. built and U.S. manned.

The oceangoing ships used in the study were selected as typical ships which either meet the current operational size requirements for the System, or which were assumed to be of a potential size for future Systems operation subsequent to structural modifications to the System. These ships were selected by R. M. Scher of the University of Michigan [4] under a contract for this portion of the study.

The Great Lakes bulk carriers were designed by R. A. Stern, Inc. [5] under a subcontract to the University of Michigan. These fourteen ships were judged to be an adequate cross-section of possible lake ship sizes, ranging from the largest ship currently operable through the Upper Great Lakes, to the largest ship deemed feasible to be built and operated on the Great Lakes.

3.1 Ship Capital Costs

The capital construction costs for the nineteen ships examined in the "Maximum Ship Size Study" were estimated by the University of Michigan [4, 6]. The cost estimates were based on the costs of steel, shipyard labor, and shipyard overhead and are given in the study as January 1977 costs.

The ship construction costs were updated to January 1981 dollars using the "Building Cost Index" from *Engineering News Record* which accounts for increases in the costs of skilled labor and materials. These cost indices yield similar cost escalation figures to those published by the Maritime Administration. The Maritime Administration figures could not be used in this cost update study because unprecedented ship sizes were used in the "Maximum Ship Size Study". In addition, Marad's figures are available only on an annual basis whereas the ENR indices are prepared on a monthly basis. A summary of the construction cost for each ship in both January 1977 and January 1981 dollars is given in Table 5.

TABLE 5 SHIP CONSTRUCTION COSTS

| SHIP TYPE | SIZE | COST (1000\$) | |
|---------------------|---------------|---------------|---------|
| | | JAN. 77 | JAN. 81 |
| Ocean-Container | 730x75 | 36,640 | 49,980 |
| Ocean-Container | 940x105 | 57,560 | 78,510 |
| Ocean-Bulk | 730x75 | 20,530 | 28,000 |
| Ocean-Bulk | 1000x130 | 41,930 | 57,190 |
| Ocean-General Cargo | 730x75 | 17,610 | 24,020 |
| Lake-Bulk | 1000x105x56 | 39,830 | 54,330 |
| Lake-Bulk | 1100x105x56 | 44,110 | 60,170 |
| Lake-Bulk | 1200x105x65 | 49,060 | 66,920 |
| Lake-Bulk | 1200x130x65 | 54,290 | 74,050 |
| Lake-Bulk | 1200x130x74 | 54,420 | 74,230 |
| Lake-Bulk | 1200x175x65 | 68,640 | 93,630 |
| Lake-Bulk | 1200x175x74 | 68,730 | 93,750 |
| Lake-Bulk | 1300x130x65 | 59,090 | 80,600 |
| Lake-Bulk | 1300x130x69.5 | 59,050 | 80,540 |
| Lake-Bulk | 1300x130x74 | 59,020 | 80,500 |
| Lake-Bulk | 1300x175x65 | 73,660 | 100,470 |
| Lake-Bulk | 1300x175x69.5 | 73,550 | 100,320 |
| Lake-Bulk | 1300x175x74 | 73,740 | 100,580 |
| Lake-Bulk | 1500x175x74 | 87,220 | 118,970 |

ENR Building Cost Index: Jan. 77 = 1489;
 Jan. 81 = 2031;
 Base: 1913 = 100

Lake Bulk carriers are self-unloading dry bulk carriers.

3.2 Ship Operating Costs

The annual operating costs for the nineteen ships studied in the "Maximum Ship Size Study" were also estimated by the University of Michigan [6]. These annual costs include the costs for fuel, maintenance and repair, insurance, crew, overhead, towing, and layup.

It was assumed in the study that the oceangoing ships would operate at maximum draft for the ocean portion of their voyage and then unload at Montreal to meet allowable Seaway draft restrictions. For this reason, the University of Michigan was able to determine that the influence of Seaway draft on the operating costs of the oceangoing ships becomes negligible. The lake ships must operate at the allowable System draft at all times, therefore the effect of draft on the operating costs of the lake ships was taken into account [6].

The costs of operating the lake ships during periods of extended winter navigation were also taken into account in the "Maximum Ship Size Study". Estimates were made of the annual operating costs for 8.5 month, 10 month, and 12 month seasons.

The operating costs for the "Maximum Ship Size Study" were given in January 1977 dollars. The costs were updated to January 1981 dollars by increasing the fuel costs to reflect the current diesel fuel price of approximately \$309/long ton, and by increasing the other cost items using the *Engineering News Record* "Construction Cost Index". These updated ship operating costs are comparable with those published by the Maritime Administration. A summary of the operating costs for oceangoing ships is given in Table 6. A summary of the operating costs for lake ships, by length of season, is given in Tables 7A, B, and C.

3.3 Required Freight Rates

Required freight rate (RFR), as used in the "Maximum Ship Size Study", is defined as the shipping charge for the goods being transported that will yield a 10% after-tax return on the ship investment. The following equation was used to calculate required freight rates:

$$RFR = \frac{CRF \times CC + ACC}{Capacity} \quad (1)$$

TABLE 6 ANNUAL OCEAN SHIP OPERATING COSTS (1000 \$/YR)

| SHIP TYPE/SIZE | EUROPE | | JAPAN | |
|-----------------------------|------------------|-------------|---------|---------|
| | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 |
| Container | | | | |
| 730x75 | 3,621 | 10,551 | 4,501 | 14,177 |
| 940x105 | 5,754 | 17,222 | 7,837 | 25,804 |
| Bulk Carriers | | | | |
| 730x75 | 2,310 | 6,021 | 2,399 | 6,388 |
| 1000x130 | 4,382 | 12,093 | 4,672 | 13,288 |
| General Cargo | | | | |
| 730x75 | 2,653 | 7,239 | 3,222 | 9,583 |
| Diesel Fuel Cost: | Jan. 1977 | \$ 75/L.ton | | |
| | Jan. 1981 | \$309/L.ton | | |
| ENR Construction Cost Index | Jan. 1977 | 2494 | | |
| | Jan. 1981 | 3400 | | |
| | Base: 1913 = 100 | | | |

TABLE 7A ANNUAL LAKE SHIP OPERATING COSTS (1000 \$/YR)
8.5 MONTH SEASON

| SHIP SIZE | DRAFT = 25.5 | | DRAFT = 28 | | DRAFT = 32 | | DRAFT = 36 | |
|---------------|--------------|---------|------------|---------|------------|---------|------------|---------|
| | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 |
| 1000x105x56 | 2,373 | 5,208 | 2,387 | 5,250 | 2,401 | 5,291 | NP | NP |
| 1100x105x56 | 2,629 | 5,901 | 2,629 | 5,899 | 2,603 | 5,821 | NP | NP |
| 1200x105x56 | 2,997 | 6,928 | 2,982 | 6,881 | 2,920 | 6,695 | NP | NP |
| 1200x130x65 | 3,115 | 7,086 | 3,158 | 7,214 | 3,178 | 7,273 | NP | NP |
| 1200x130x74 | 3,154 | 7,145 | 3,201 | 7,283 | 3,223 | 7,351 | 3,241 | 7,407 |
| 1200x175x65 | 4,395 | 9,944 | 4,360 | 9,844 | 4,363 | 9,852 | NP | NP |
| 1200x175x74 | 4,456 | 10,751 | 4,423 | 10,650 | 4,428 | 10,665 | 4,447 | 10,721 |
| 1300x130x65 | 3,311 | 7,580 | 3,357 | 7,717 | 3,378 | 7,780 | NP | NP |
| 1300x130x69.5 | 3,346 | 7,657 | 3,395 | 7,802 | 3,418 | 7,871 | NP | NP |
| 1300x130x74 | 3,376 | 7,717 | 3,426 | 7,866 | 3,450 | 7,939 | 3,440 | 7,908 |
| 1300x175x65 | 4,392 | 10,511 | 4,357 | 10,406 | 4,360 | 10,414 | NP | NP |
| 1300x175x69.5 | 4,434 | 10,601 | 4,402 | 10,502 | 4,407 | 10,518 | NP | NP |
| 1300x175x74 | 4,458 | 10,634 | 4,425 | 10,534 | 4,430 | 10,549 | 4,474 | 10,682 |
| 1500x175x74 | 4,518 | 10,533 | 4,590 | 10,748 | 4,668 | 10,982 | 4,710 | 11,109 |

NP denotes no plan in the "Maximum Ship Size Study".

ENR "Construction Cost Index" Jan. 1977 = 2494
Jan. 1981 = 3400
Base: 1913 = 100

TABLE 7B ANNUAL LAKE SHIP OPERATING COSTS (1000 \$/YR)
10 MONTH SEASON

| SHIP SIZE | DRAFT = 25.5 | | DRAFT = 28 | | DRAFT = 32 | | DRAFT = 36 | |
|---------------|--------------|---------|------------|---------|------------|---------|------------|---------|
| | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 |
| 1000x105x56 | 2,841 | 6,231 | 2,858 | 6,280 | 2,876 | 6,334 | NP | NP |
| 1100x105x56 | 3,149 | 7,062 | 3,149 | 7,060 | 3,118 | 6,968 | NP | NP |
| 1200x105x56 | 3,591 | 8,292 | 3,573 | 8,238 | 3,500 | 8,017 | NP | NP |
| 1200x130x65 | 3,719 | 8,497 | 3,772 | 8,603 | 3,797 | 8,676 | NP | NP |
| 1200x130x74 | 3,760 | 8,511 | 3,817 | 8,678 | 3,846 | 8,763 | 3,869 | 8,833 |
| 1200x175x65 | 5,243 | 12,669 | 5,205 | 12,553 | 5,211 | 12,570 | NP | NP |
| 1200x175x74 | 5,310 | 12,794 | 5,273 | 12,953 | 5,283 | 12,710 | 5,308 | 12,784 |
| 1300x130x65 | 3,954 | 9,091 | 4,010 | 9,205 | 4,037 | 9,283 | NP | NP |
| 1300x130x69.5 | 3,994 | 9,126 | 4,053 | 9,301 | 4,082 | 9,387 | NP | NP |
| 1300x130x74 | 4,027 | 9,193 | 4,088 | 9,373 | 4,119 | 9,465 | 4,107 | 9,432 |
| 1300x175x65 | 5,228 | 12,479 | 5,190 | 12,364 | 5,196 | 12,381 | NP | NP |
| 1300x175x69.5 | 5,276 | 12,583 | 5,239 | 12,472 | 5,248 | 12,498 | NP | NP |
| 1300x175x74 | 5,301 | 12,617 | 5,264 | 12,506 | 5,274 | 12,534 | 5,329 | 12,698 |
| 1500x175x74 | 5,380 | 12,512 | 5,468 | 12,774 | 5,563 | 10,059 | 5,617 | 13,220 |

NP denotes no plan in the "Maximum Ship Size Study".

ENR "Construction Cost Index" Jan. 1977 = 2494
Jan. 1981 = 3400
Base: 1913 = 100

TABLE 7C ANNUAL LAKE SHIP OPERATING COSTS (1000 \$/YR)
12 MONTH SEASON

| SHIP SIZE | DRAFT = 25.5 | | DRAFT = 28 | | DRAFT = 32 | | DRAFT = 36 | |
|---------------|--------------|---------|------------|---------|------------|---------|------------|---------|
| | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 | JAN. 77 | JAN. 81 |
| 1000x105x56 | 3,507 | 7,519 | 3,530 | 7,587 | 3,555 | 7,660 | NP | |
| 1100x105x56 | 3,890 | 8,516 | 3,894 | 8,527 | 3,862 | 8,433 | NP | |
| 1200x105x56 | 4,431 | 9,979 | 4,414 | 9,928 | 4,333 | 9,688 | NP | |
| 1200x130x65 | 4,613 | 10,210 | 4,143 | 10,408 | 4,715 | 10,513 | NP | |
| 1200x130x74 | 4,661 | 10,287 | 4,731 | 10,492 | 4,771 | 10,610 | 4,805 | 10,710 |
| 1200x175x65 | 6,464 | 15,220 | 6,425 | 15,101 | 6,443 | 15,154 | NP | |
| 1200x175x74 | 6,541 | 15,362 | 6,540 | 15,249 | 6,524 | 15,310 | 6,563 | 15,423 |
| 1300x130x65 | 4,914 | 10,936 | 4,985 | 11,148 | 5,023 | 11,261 | NP | |
| 1300x130x69.5 | 4,958 | 11,036 | 5,032 | 11,254 | 5,073 | 11,375 | NP | |
| 1300x130x74 | 4,996 | 11,112 | 5,071 | 11,333 | 5,114 | 11,461 | 5,107 | 11,441 |
| 1300x175x65 | 6,481 | 15,058 | 6,442 | 14,941 | 6,460 | 14,993 | NP | |
| 1300x175x69.5 | 6,534 | 15,171 | 6,497 | 15,061 | 6,517 | 15,119 | NP | |
| 1300x175x74 | 6,563 | 15,211 | 6,526 | 15,100 | 6,546 | 15,160 | 6,621 | 15,380 |
| 1500x175x74 | 6,731 | 15,203 | 6,841 | 15,529 | 6,965 | 15,895 | 7,038 | 16,114 |

NP denotes no plan in the "Maximum Ship Size Study".

ENR "Construction Cost Index" Jan. 1977 = 2494
Jan. 1981 = 3400
Base: 1913 = 100

where:

RFR = required freight rate (\$/long ton),

CRF = capital recovery factor that will allow a 10% after-tax return on investment for the design life of the ship, based on a 48% corporate tax rate,

CC = capital cost of constructing the ship (\$),

AOC = annual cost of operating the ship (\$/yr)

Capacity = annual amount of cargo hauled (long tons/yr).

Since both the annual operating costs and the amount of cargo that can be hauled change with route, RFR's are route specific. The "Maximum Ship Size Study" determined the RFR's for several typical routes for each ship class.

Required freight rates also vary with the length of the shipping season. Three season scenarios were analyzed for oceangoing ships and three season scenarios were analyzed for lake ships. The oceangoing ship scenarios are:

338 days: Full-year GL/SLS operation,

254 days: 8.5 month GL/SLS operation with off-season use elsewhere,

254 days: 8.5 month operation with off-season layup.

The lake ship scenarios consist of 8.5, 10, and 12 month season with the ships being idle for the remainder of the year.

The required freight rates for all the ships and routes used in the "Maximum Ship Size Study" were given in January 1977 dollars in the unpublished Appendix A of the Study. The RFR's are updated to January 1981 dollars in this report, using the updated ship construction costs from Table 5 and the updated ship operating costs from Tables 6 and 7. This approach assumes that the defined return of 10% after 48% corporate tax is still an appropriate return on investment. A summary of the required freight rates for the oceangoing ships in the "Maximum Ship Size Study" is given in Tables 8A through D. A summary of the required freight rates of the lake ships is given in Tables 9A through D. The updated required freight rates are summarized in Tables 2A, 2B, and 3.

TABLE 8A OCEAN-GOING SHIPS RFR'S (JAN. 77 \$)
SHIP DRAFT = 25.5 FT

| SHIP TYPE | ROUTE ¹ | REQUIRED FREIGHT RATES | | | | |
|-----------------------------|--------------------|------------------------|---------------------|---------------------|---------------------|---------------------|
| | | 338 da ² | 254 da ³ | 254 da ⁴ | 338 da ² | 254 da ³ |
| | | 730 x 75 | | | 940 x 105 | |
| Container Ship ⁵ | Rot-Mon | 435.51 | 437.63 | 486.28 | 418.09 | 420.19 |
| | Det | 540.22 | 542.94 | 605.38 | 532.30 | 534.97 |
| | Chi | 647.29 | 650.54 | 725.35 | 649.94 | 653.21 |
| | Yok-Mon | 899.14 | 912.83 | 1,060.28 | 800.03 | 808.10 |
| | Det | 943.46 | 957.83 | 1,112.55 | 839.46 | 847.94 |
| | Chi | 988.87 | 1,003.93 | 1,166.09 | 879.86 | 888.75 |
| | Rot-Mon | 433.70 | 435.88 | 487.24 | 414.66 | 418.43 |
| | Cle | 523.82 | 526.45 | 588.48 | 511.09 | 515.73 |
| | Det | 538.01 | 540.71 | 604.42 | 528.01 | 532.81 |
| | | 730 x 75 | | | 1000 x 130 | |
| Bulk Carrier ⁶ | Chi-Rot | 19.75 | 19.75 | 23.79 | 11.62 | 11.67 |
| | w/Bai-Rot | 14.10 | 14.10 | 16.98 | 8.30 | 8.33 |
| | Dul-Jap | 46.12 | 46.37 | 55.71 | 25.79 | 26.02 |
| | w/Bai-Jap | 40.64 | 40.86 | 49.09 | 22.73 | 22.93 |
| | | 730 x 75 | | | | |
| General Cargo ⁶ | Jap-Mon | 25.26 | 25.29 | 29.51 | | |
| | Det | 26.51 | 26.54 | 30.97 | | |
| | Chi | 27.77 | 27.81 | 32.45 | | |
| | Rot-Mon | 9.58 | 9.60 | 11.31 | | |
| | Det | 11.22 | 11.24 | 13.24 | | |
| | Chi | 12.85 | 12.88 | 15.17 | | |

TABLE 38 OCEAN-GOING SHIPS RFR'S (JAN. 77 \$)
SHIP DRAFT = 28 FT

| SHIP TYPE | ROUTE ¹ | REQUIRED FREIGHT RATES | | | | | |
|-----------------------------|--------------------|------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| | | 338 da ² | 254 da ³ | 254 da ⁴ | 338 da ² | 254 da ³ | 254 da ⁴ |
| | | 730 x 75 | | | 940 x 105 | | |
| Container Ship ⁵ | Rot-Mon | 435.51 | 437.63 | 486.28 | 418.09 | 420.19 | 464.17 |
| | Det | 524.72 | 527.36 | 588.00 | 512.58 | 515.16 | 568.74 |
| | Chi | 615.93 | 619.03 | 690.22 | 609.93 | 612.99 | 676.74 |
| | Yok-Mon | | | Not Studied | | | |
| | Det | | | Not Studied | | | |
| | Chi | | | Not Studied | | | |
| | Rot-Mon | 433.70 | 435.88 | 487.24 | 414.66 | 418.43 | 468.85 |
| | Cle | 510.49 | 513.06 | 573.51 | 494.45 | 498.94 | 559.06 |
| | Det | 522.57 | 525.20 | 587.08 | 507.46 | 512.07 | 573.78 |
| | | | 730 x 75 | | | 1000 x 130 | |
| Bulk Carrier ⁶ | Chi-Rot | 19.58 | 19.58 | 23.58 | 11.55 | 11.57 | 13.98 |
| | w/Bai-Rot | 13.97 | 13.97 | 16.83 | 8.23 | 8.25 | 9.97 |
| | Dul-Jap | 45.73 | 45.98 | 55.24 | 25.62 | 25.80 | 31.10 |
| | w/Bai-Jap | 40.27 | 40.49 | 48.64 | 22.56 | 22.72 | 27.49 |
| | | | 730 x 75 | | | | |
| | Jap-Mon | 24.50 | 24.53 | 28.62 | | | |
| General Cargo ⁶ | Det | 25.71 | 25.74 | 30.03 | | | |
| | Chi | 26.94 | 26.98 | 31.48 | | | |
| | Rot-Mon | 9.35 | 9.37 | 11.04 | | | |
| | Det | 10.90 | 10.92 | 12.86 | | | |
| | Chi | 12.48 | 12.51 | 14.73 | | | |
| | | | 730 x 75 | | | | |

TABLE 8C OCEAN-GOING SHIPS RFR'S (JAN. 77 \$)
SHIP DRAFT = 32 FT

| SHIP TYPE | ROUTE ¹ | REQUIRED FREIGHT RATES | | | | |
|-----------------------------|--------------------|------------------------|---------------------|---------------------|---------------------|---|
| | | 338 da ² | 254 da ³ | 254 da ⁴ | 338 da ² | 254 da ³ 254 da ⁴ |
| | | | 730 x 75 | | 940 x 105 | |
| Container Ship ⁵ | Rot-Mon | 435.51 | 437.63 | 486.28 | 418.09 | 420.19 464.17 |
| | Det | 507.65 | 510.20 | 568.87 | 494.17 | 496.65 548.30 |
| | Chi | 581.40 | 584.32 | 651.52 | 572.53 | 575.41 635.25 |
| | Yok-Mon | | | Not Studied | | |
| | Det | | | Not Studied | | |
| | Cni | | | Not Studied | | |
| | Rot-Mon | 433.70 | 435.88 | 487.24 | 414.66 | 418.43 468.85 |
| | Cle | 495.80 | 498.29 | 557.00 | 478.89 | 483.24 541.47 |
| | Det | 505.57 | 508.11 | 567.98 | 490.15 | 494.60 554.20 |
| | | | 730 x 75 | | 1000 x 130 | |
| Bulk Carrier ⁶ | Chi-Rot | 18.40 | 18.37 | 21.13 | 10.88 | 10.88 13.15 |
| | w/Bai-Rot | 13.13 | 13.11 | 15.79 | 7.74 | 7.74 9.35 |
| | Dul-Jap | 45.04 | 45.28 | 54.40 | 25.25 | 25.40 30.62 |
| | w/Bai-Jap | 39.69 | 39.90 | 47.94 | 22.25 | 22.38 26.98 |
| | | | 730 x 75 | | | |
| | Jap-Mon | 0 | 0 | 0 | | |
| | Det | 24.39 | 24.42 | 28.50 | | |
| | Chi | 25.54 | 25.58 | 29.85 | | |
| | Rot-Mon | 0 | 0 | 0 | | |
| | Det | 10.34 | 10.36 | 12.20 | | |
| | Chi | 11.84 | 11.87 | 13.98 | | |

TABLE 80 OCEAN-GOING SHIPS RFR'S (JAN. 77 \$)
SHIP DRAFT = 36 FT

| SHIP TYPE | ROUTE ¹ | REQUIRED FREIGHT RATES | | | |
|-----------------------------|--------------------|------------------------|---------------------|---------------------|---------------------|
| | | 338 da ² | 254 da ³ | 254 da ⁴ | 254 da ⁴ |
| | | 730 x 75 | | | |
| Container Ship ⁵ | Rot-Mon | | Not Studied | 418.09 | 420.19 |
| | Det | | Not Studied | 487.41 | 489.86 |
| | Chi | | Not Studied | 558.82 | 561.63 |
| | Yok-Mon | | Not Studied | | Not Studied |
| | Det | | Not Studied | | Not Studied |
| | Chi | | Not Studied | | Not Studied |
| | Rot-Mon | | Not Studied | 414.66 | 418.43 |
| | Cle | | Not Studied | 473.20 | 477.49 |
| | Det | | Not Studied | 483.87 | 487.86 |
| | | | | | 1000 x 130 |
| Bulk Carrier ⁶ | Chi-Rot | | Not Studied | 10.22 | 10.20 |
| | w/Bai-Rot | | Not Studied | 7.27 | 7.26 |
| | Dul-Jap | | Not Studied | 24.88 | 24.98 |
| | w/Bai-Jap | | Not Studied | 21.92 | 22.01 |
| | | 730 x 75 | | | |
| General Cargo ⁶ | Jap-Mon | | Not Studied | | |
| | Det | | Not Studied | | |
| | Chi | | Not Studied | | |
| | Rot-Mon | | Not Studied | | |
| | Det | | Not Studied | | |

TABLES 8A - 8D (CONTINUED)

NOTES

1. Ship Routes:

Container Ships

- a. Rotterdam to Montreal, Detroit, and Chicago
- b. Yokohama to Montreal, Detroit, and Chicago
- c. Rotterdam to Montreal, Cleveland, and Detroit

Import-export containers, loads equally divided between all ports, available Seaway draft always utilized.

Bulk Carriers

- a. Chicago to Rotterdam
- b. Duluth to Japan

Ships top-off to maximum draft at Baie Commeau. Empty backhaul.

General Cargo

- a. Japan to Montreal, Detroit, and Chicago
- b. Rotterdam to Montreal, Detroit, and Chicago

Import-export. Seaway cargo equally divided between Chicago and Detroit. Loading or unloading at Montreal only to available Seaway draft.

- 2. 338 day season: year-round operation with 22 day lay-up for maintenance.
- 3. 254 day season: 8.5 month operation with a transfer of service to other operations during winter.
- 4. 254 day season: 8.5 month operation with lay-up during winter months.
- 5. Container ship RFR in \$/TEU.
- 6. Bulk carrier and General Cargo Ship RFR in \$/L.ton.

TABLE 9A GREAT LAKES BULK CARRIERS RFR'S (JAN. 77 \$/L. TON)
SHIP BULK DRAFT = 25.5 ft

| SHIP SIZE | DULUTH-CHICAGO | | | TWO HARBORS-CLEVELAND | | | DULUTH-BAIE COMMEAU | | |
|---------------|----------------|--------|--------|-----------------------|--------|-------------|---------------------|--------|--------|
| | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. |
| 1000x105x56 | 3.30 | 3.03 | 3.02 | 3.28 | 3.01 | 2.97 | 3.66 | 3.27 | 2.79 |
| 1000x130x56 | 3.07 | 2.82 | 2.81 | | | Not Studied | | | |
| 1000x175x56 | 3.26 | 3.00 | 3.00 | | | Not Studied | | | |
| 1100x105x56 | 3.35 | 3.08 | 3.07 | 3.33 | 3.05 | 3.02 | 4.19 | 3.83 | 3.71 |
| 1100x130x56 | 3.02 | 2.79 | 2.77 | | | Not Studied | | | |
| 1100x175x56 | 3.18 | 2.93 | 2.93 | | | Not Studied | | | |
| 1200x105x56 | 3.48 | 3.20 | 3.19 | 3.45 | 3.17 | 3.13 | 4.32 | 3.96 | 3.84 |
| 1200x130x65 | 2.91 | 2.69 | 2.69 | 2.90 | 2.67 | 2.65 | 3.64 | 3.33 | 3.22 |
| 1200x130x74 | 2.91 | 2.68 | 2.67 | 2.89 | 2.66 | 2.64 | 3.64 | 3.34 | 3.23 |
| 1200x175x65 | 2.91 | 2.68 | 2.67 | 2.89 | 2.66 | 2.64 | 3.59 | 3.29 | 3.20 |
| 1200x175x74 | 2.89 | 2.66 | 2.63 | 2.87 | 2.64 | 2.61 | 3.58 | 3.30 | 3.21 |
| 1300x130x65 | 2.98 | 2.75 | 2.74 | 2.96 | 2.72 | 2.69 | 3.71 | 3.40 | 3.29 |
| 1300x130x69.5 | 2.94 | 2.72 | 2.71 | 2.92 | 2.69 | 2.66 | 3.67 | 3.36 | 3.25 |
| 1300x130x74 | 2.92 | 2.70 | 2.69 | 2.90 | 2.68 | 2.65 | 3.66 | 3.36 | 3.25 |
| 1300x175x65 | 2.84 | 2.64 | 2.63 | 2.82 | 2.62 | 2.59 | 3.51 | 3.24 | 3.15 |
| 1300x175x69.5 | 2.81 | 2.62 | 2.61 | 2.79 | 2.60 | 2.57 | 3.49 | 3.22 | 3.13 |
| 1300x175x74 | 2.81 | 2.62 | 2.61 | 2.79 | 2.56 | 2.57 | 3.48 | 3.21 | 3.13 |
| 1500x175x74 | 2.82 | 2.61 | 2.60 | 2.80 | 2.59 | 2.56 | 3.52 | 3.23 | 3.12 |

TABLE 9B GREAT LAKES BULK CARRIERS RFR'S (JAN. 77 \$/L. TON)
SHIP BULK DRAFT = 28 ft

| SHIP SIZE | DULUTH-CHICAGO | | | TWO HARBORS-CLEVELAND | | | DULUTH-BAIE COMMEAU | | |
|---------------|---------------------------|--------|--------|---------------------------|--------|-------------|---------------------------|--------|--------|
| | RET. SEPT ISLES-CLEVELAND | | | RET. SEPT ISLES-CLEVELAND | | | RET. SEPT ISLES-CLEVELAND | | |
| | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. |
| 1000x105x56 | 2.95 | 2.71 | 2.70 | 2.93 | 2.69 | 2.66 | 3.78 | 3.38 | 2.89 |
| 1000x130x56 | 2.76 | 2.54 | 2.53 | | | Not Studied | | | |
| 1000x175x56 | 2.88 | 2.66 | 2.65 | | | Not Studied | | | |
| 1100x105x56 | 2.99 | 2.74 | 2.73 | 2.97 | 2.72 | 2.69 | 3.72 | 3.41 | 3.29 |
| 1100x130x56 | 2.72 | 2.51 | 2.50 | | | Not Studied | | | |
| 1100x175x56 | 2.82 | 2.61 | 2.61 | | | Not Studied | | | |
| 1200x105x56 | 3.09 | 2.84 | 2.83 | 3.07 | 2.81 | 2.78 | 3.84 | 3.51 | 3.40 |
| 1200x130x65 | 2.61 | 2.42 | 2.42 | 2.60 | 2.40 | 2.37 | 3.27 | 3.00 | 2.90 |
| 1200x130x74 | 2.61 | 2.41 | 2.39 | 2.59 | 2.39 | 2.36 | 3.26 | 2.98 | 2.89 |
| 1200x175x65 | 2.58 | 2.39 | 2.38 | 2.56 | 2.37 | 2.35 | 3.18 | 2.93 | 2.85 |
| 1200x175x74 | 2.56 | 2.37 | 2.35 | 2.54 | 2.35 | 2.33 | 3.16 | 2.91 | 2.83 |
| 1300x130x65 | 2.67 | 2.46 | 2.45 | 2.65 | 2.44 | 2.41 | 3.32 | 3.04 | 2.94 |
| 1300x130x69.5 | 2.64 | 2.44 | 2.43 | 2.62 | 2.41 | 2.39 | 3.28 | 3.00 | 2.91 |
| 1300x130x74 | 2.62 | 2.42 | 2.41 | 2.60 | 2.40 | 2.37 | 3.27 | 3.00 | 2.90 |
| 1300x175x65 | 2.52 | 2.35 | 2.34 | 2.50 | 2.33 | 2.30 | 3.12 | 2.87 | 2.79 |
| 1300x175x69.5 | 2.50 | 2.32 | 2.32 | 2.48 | 2.30 | 2.28 | 3.09 | 2.85 | 2.77 |
| 1300x175x74 | 2.50 | 2.32 | 2.32 | 2.48 | 2.30 | 2.28 | 3.09 | 2.85 | 2.77 |
| 1500x175x74 | 2.52 | 2.34 | 2.32 | 2.51 | 2.32 | 2.29 | 3.14 | 2.88 | 2.79 |

TABLE 9C GREAT LAKES BULK CARRIERS RFR'S (JAN. 77 \$/L. TON)
SHIP BULK DRAFT = 32 ft

| SHIP SIZE | DULUTH-CHICAGO | | | TWO HARBORS-CLEVELAND | | | DULUTH-BAIE COMMEAU | | |
|---------------|----------------|--------|--------|-----------------------|--------|-------------|---------------------|--------|--------|
| | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. |
| 1000x105x56 | 2.54 | 2.33 | 2.32 | 2.52 | 2.31 | 2.28 | 4.14 | 3.69 | 3.16 |
| 1000x130x56 | 2.40 | 2.20 | 2.20 | | | Not Studied | | | |
| 1000x175x56 | 2.44 | 2.25 | 2.24 | | | Not Studied | | | |
| 1100x105x56 | 2.54 | 2.33 | 2.33 | 2.53 | 2.31 | 2.29 | 3.16 | 2.89 | 2.79 |
| 1100x130x56 | 2.36 | 2.17 | 2.16 | | | Not Studied | | | |
| 1100x175x56 | 2.41 | 2.23 | 2.22 | | | Not Studied | | | |
| 1200x105x56 | 2.61 | 2.40 | 2.39 | 2.60 | 2.38 | 2.35 | 3.24 | 2.96 | 2.87 |
| 1200x130x65 | 2.25 | 2.08 | 2.07 | 2.24 | 2.06 | 2.03 | 2.80 | 2.56 | 2.48 |
| 1200x130x74 | 2.24 | 2.07 | 2.06 | 2.22 | 2.05 | 2.03 | 2.78 | 2.55 | 2.47 |
| 1200x175x65 | 2.20 | 2.04 | 2.03 | 2.18 | 2.02 | 2.00 | 2.70 | 2.49 | 2.41 |
| 1200x175x74 | 2.18 | 2.02 | 2.02 | 2.16 | 2.00 | 1.98 | 2.68 | 2.47 | 2.40 |
| 1300x130x65 | 2.29 | 2.11 | 2.10 | 2.27 | 2.09 | 2.07 | 2.84 | 2.60 | 2.51 |
| 1300x130x69.5 | 2.26 | 2.08 | 2.08 | 2.24 | 2.06 | 2.04 | 2.79 | 2.56 | 2.48 |
| 1300x130x74 | 2.24 | 2.07 | 2.06 | 2.22 | 2.05 | 2.02 | 2.79 | 2.55 | 2.47 |
| 1300x175x65 | 2.16 | 2.01 | 2.00 | 2.14 | 1.99 | 1.97 | 2.66 | 2.45 | 2.38 |
| 1300x175x69.5 | 2.13 | 1.98 | 1.98 | 2.12 | 1.97 | 1.95 | 2.63 | 2.43 | 2.36 |
| 1300x175x74 | 2.13 | 1.98 | 1.98 | 2.12 | 1.97 | 1.95 | 2.63 | 2.42 | 2.36 |
| 1500x175x74 | 2.16 | 2.00 | 1.99 | 2.15 | 1.99 | 1.96 | 2.68 | 2.46 | 2.38 |

TABLE 9D GREAT LAKES BULK CARRIERS RFR'S (JAN. 77 \$/L. TON)
SHIP BULK DRAFT = 36 ft

| SHIP SIZE | DULUTH-CHICAGO | | | TWO HARBORS-CLEVELAND | | | DULUTH-BAIE COMMEAU RET. SEPT ISLES-CLEVELAND | | |
|---------------|----------------|--------|--------|-----------------------|--------|-------------|--|--------|--------|
| | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. | 8.5 MO. | 10 MO. | 12 MO. |
| 1000x105x56 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1000x130x56 | 2.14 | 1.96 | 1.96 | | | Not Studied | | | |
| 1000x175x56 | 2.10 | 1.92 | 1.91 | | | Not Studied | | | |
| 1100x105x56 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1100x130x56 | 2.10 | 1.91 | 1.90 | | | Not Studied | | | |
| 1100x175x56 | 2.05 | 1.87 | 1.87 | | | Not Studied | | | |
| 1200x105x56 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1200x130x65 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1200x130x74 | 1.96 | 1.81 | 1.81 | 1.95 | 1.80 | 1.78 | 2.44 | 2.23 | 2.16 |
| 1200x175x65 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1200x175x74 | 1.92 | 1.77 | 1.77 | 1.90 | 1.75 | 1.74 | 2.34 | 2.16 | 2.10 |
| 1300x130x65 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1300x130x69.5 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1300x130x74 | 1.95 | 1.80 | 1.79 | 1.94 | 1.79 | 1.77 | 2.42 | 2.22 | 2.15 |
| 1300x175x65 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1300x175x69.5 | NP | NP | NP | NP | NP | NP | NP | NP | NP |
| 1300x175x74 | 1.87 | 1.74 | 1.74 | 1.86 | 1.73 | 1.71 | 2.30 | 2.12 | 2.06 |
| 1500x175x74 | 1.90 | 1.76 | 1.75 | 1.89 | 1.75 | 1.72 | 2.34 | 2.15 | 2.08 |

4. STRUCTURAL AND NON-STRUCTURAL COSTS

The largest ship which may pass through the St. Lawrence River Locks and the Welland Canal Locks has a length of 730 ft, a beam of 76 ft, and a draft of 25.5 ft at low water datum. The largest ship that may pass through the Soo Locks has a length of 1000 ft, a beam of 105 ft, and a draft of 25.5 ft at low water datum [3]. Most of the Great Lakes harbors and connecting channels have the capability of handling similarly sized ships. Ship draft is limited due to the depth of most of the harbors and channels. Therefore, major improvements to the locks, harbors, and connecting channels would be required to accomodate most of the ships considered in the "Maximum Ship Size Study".

4.1 Connecting Channels

The major connecting channels on the GL/SLS System would require dredging to allow safe passage of larger ships. The channels that would have to be modified are:

1. St. Marys River
2. Straits of Mackinac
3. St. Clair River-Lakes St. Clair-Detroit River-Pelee Passage
4. Welland Canal
5. St. Lawrence River.

Gray's Reef Passage in Lake Michigan was also considered for modification, however, it was not included in the study because the savings in transit time could not justify the high cost of improving the passage [1].

The connecting channels were sized by a computer program developed as part of the "Maximum Ship Size Study". The Rock Island District of the Corps of Engineers estimated the quantities of dredging required for 1100 x 105 ft, 1200 x 130 ft, and 1300 x 175 ft ships at four drafts [7]. Quantities for intermediate size ships were extrapolated using the significant dimensions. Quantities for the 1300 by 130 ft ships were estimated to be less than those for the 1200 by 130 ft ship in Lake St. Clair because the 1300 ft long hull is more hydrodynamically efficient in open water and therefore will have less squat [1]. In a narrower channel such as the St. Mary's River, bank effects dominate the channel sizing and therefore the dredging estimates are strictly beam dependant and are independant of ship length [1].

Unit costs of \$8/yd³ for overburden and \$45/yd³ for rock were used to estimate dredging costs for all channels except the Welland Canal, where the unit costs were \$5/yd³ for overburden and \$25/yd³ for rock. These unit costs include the cost of disposing of the dredged material in appropriate sites.

The dredging unit costs were escalated using the *Engineering News Record* "Construction Cost Index" to update them from August 1977 dollars to January 1981 dollars. The dredging quantities, the original cost from the Study, and the updated costs are given in Tables 10A through D.

An investigation was made of the effects that channel dredging would have on the water levels in the channels by the North Central Division Water Control Center. It concluded from this work that some form of compensating structure would be required on the St. Marys River, the St. Clair River, and the Detroit River. No compensating structures were deemed necessary for the St. Lawrence River which is well controlled by locks and dams.

The "Maximum Ship Size Study" assumed that the compensating structures would be of the type proposed by the International Great Lakes Levels Board report to the International Joint Commission, entitled "Regulation of Great Lakes Water Levels". The costs originally estimated in the Study for the compensating structures are given in Table 11, along with updated January 1981 costs.

4.2 Locks

Analysis of the costs for increasing the size of all the locks on the GL/SLS System was performed by the Rock Island District [8]. The analysis also reflects an optimization of the lock system by combining into single locks, the Snell Lock with the Eisenhower Lock and the Upper Beauharnois Lock with the Lower Beauharnois Lock. The Welland Canal was assumed replaced with a five lock system, consisting of four high lift locks and one guard lock. An additional large lock was assumed to be constructed at the Soo. If the beam on the maximum size ship was no more than 105 ft, it was assumed that the Davis lock would be replaced. If the beam was greater than 105 ft both the Sabin and Davis locks would be replaced. An additional lock, similar to the Iroquois Lock, was included for the St. Clair River for flow control.

TABLE 10A CHANNEL DREDGING
SHIP DRAFT = 25.5 FT

| CHANNEL | SHIP SIZE | VOLUME | | COST | |
|--|-----------|---------------------------------------|---------------------------------|----------------------|----------------------|
| | | OVERBURDEN (1000 yd ³) | ROCK (1000 yd ³) | JUL. 77 (1000 \$) | JAN. 81 (1000 \$) |
| St. Marys River | 940x105 | 0 | 0 | 0 | 0 |
| | 1000x130 | Unknown | | 789,052 | 1,040,239 |
| | 1100x105 | 0 | 0 | 0 | 0 |
| | 1100x130 | Unknown | | 789,818 | 1,041,249 |
| | 1200x130 | 62,424 | 6,471 | 790,561 | 1,042,229 |
| | 1300x130 | 62,424 | 6,471 | 790,561 | 1,042,229 |
| | 1300x175 | 99,431 | 10,776 | 1,280,329 | 1,687,909 |
| Straits of Mackinac | 940x105 | 0 | 0 | 0 | 0 |
| | 1000x130 | 0 | 0 | 0 | 0 |
| | 1100x105 | 0 | 0 | 0 | 0 |
| | 1100x130 | 0 | 0 | 0 | 0 |
| | 1200x130 | 0 | 0 | 0 | 0 |
| | 1300x130 | 0 | 0 | 0 | 0 |
| | 1300x175 | 0 | 0 | 0 | 0 |
| St. Clair- Detroit R.- Pelee | 940x105 | 0 | 0 | 0 | 0 |
| | 1000x130 | Unknown | | 1,287,298 | 1,697,097 |
| | 1100x105 | 0 | 0 | 0 | 0 |
| | 1100x130 | Unknown | | 1,287,298 | 1,697,097 |
| | 1200x130 | Unknown | | 1,287,298 | 1,697,097 |
| | 1300x130 | Unknown | | 1,282,599 | 5,690,902 |
| | 1300x175 | Unknown | | 1,800,086 | 2,373,126 |
| Welland Canal | 940x105 | 114,038 | 17,954 | 1,019,028 | 1,343,426 |
| | 1000x130 | | Not Investigated | | |
| | 1100x105 | 114,038 | 17,954 | 1,019,028 | 1,343,426 |
| | 1100x130 | | Not Investigated | | |
| | 1200x130 | 140,304 | 21,095 | 1,228,894 | 1,620,101 |
| | 1300x130 | 140,304 | 21,095 | 1,228,894 | 1,620,101 |
| | 1300x175 | 199,079 | 30,575 | 1,759,763 | 2,319,967 |
| St. Lawrence River (costs include dike relocation 77: \$750,000 81: \$989,000) | 940x105 | 27,053 | 43,955 | 2,195,149 | 2,893,954 |
| | 1000x130 | | Not Investigated | | |
| | 1100x105 | 27,053 | 43,955 | 2,195,149 | 2,893,954 |
| | 1100x130 | | Not Investigated | | |
| | 1200x130 | 40,260 | 56,708 | 2,874,690 | 3,789,820 |
| | 1300x130 | 40,260 | 56,708 | 2,874,690 | 3,782,820 |
| | 1300x175 | 71,826 | 88,684 | 4,566,138 | 6,019,724 |

ENR "Construction Cost Index" Aug. 77 = 2611
Jan. 81 = 3400
Base: 1913 = 100

TABLE 108 CHANNEL DREDGING
SHIP DRAFT = 28 FT

| CHANNEL | SHIP SIZE | VOLUME | | COST | |
|--|-----------|---------------------------------------|---------------------------------|----------------------|----------------------|
| | | OVERBURDEN (1000 yd ³) | ROCK (1000 yd ³) | JUL. 77 (1000 \$) | JAN. 81 (1000 \$) |
| St. Marys River | 940x105 | 36,643 | 2,685 | 413,971 | 545,755 |
| | 1000x130 | Unknown | | 983,092 | 1,296,050 |
| | 1100x105 | 36,643 | 2,685 | 413,971 | 545,755 |
| | 1100x130 | Unknown | | 989,129 | 1,304,009 |
| | 1200x130 | 89,322 | 7,627 | 995,204 | 1,312,018 |
| | 1300x130 | Unknown | | 995,166 | 1,311,968 |
| | 1300x175 | 125,102 | 12,257 | 1,497,833 | 1,974,654 |
| Straits of Mackinac | 940x105 | 0 | 83.1 | 3,739 | 4,929 |
| | 1000x130 | 0 | 83.1 | 3,739 | 4,929 |
| | 1100x105 | 0 | 83.1 | 3,739 | 4,929 |
| | 1100x130 | 0 | 83.1 | 3,739 | 4,929 |
| | 1200x130 | 0 | 83.1 | 3,739 | 4,929 |
| | 1300x130 | 0 | 83.1 | 3,739 | 4,929 |
| | 1300x175 | 0 | 83.1 | 3,739 | 4,929 |
| St. Clair- Detroit R.- Pelee | 940x105 | 133,820 | 6,277 | 1,148,911 | 1,514,656 |
| | 1000x130 | Unknown | | 1,184,713 | 1,561,855 |
| | 1100x105 | 133,820 | 6,277 | 1,148,911 | 1,514,656 |
| | 1100x130 | Unknown | | 1,316,347 | 1,735,393 |
| | 1200x130 | 133,822 | 8,711 | 1,462,609 | 1,928,217 |
| | 1300x130 | 133,777 | 8,601 | 1,457,270 | 1,921,178 |
| | 1300x175 | 181,884 | 12,802 | 2,031,178 | 2,677,784 |
| Welland Canal | 940x105 | 122,052 | 20,788 | 1,129,971 | 1,489,686 |
| | 1000x130 | | Not Investigated | | |
| | 1100x105 | 122,052 | 20,788 | 1,129,971 | 1,489,686 |
| | 1100x130 | | Not Investigated | | |
| | 1200x130 | 151,888 | 24,519 | 1,372,410 | 1,809,304 |
| | 1300x130 | 151,888 | 24,519 | 1,372,410 | 1,809,304 |
| | 1300x175 | 206,009 | 35,356 | 1,913,939 | 2,523,223 |
| St. Lawrence River (costs include dike relocation 77: \$750,000 81: \$989,000) | 940x105 | 45,618 | 55,103 | 2,845,329 | 3,751,112 |
| | 1000x130 | | Not Investigated | | |
| | 1100x105 | 45,618 | 55,103 | 2,845,329 | 3,751,112 |
| | 1100x130 | | Not Investigated | | |
| | 1200x130 | 62,997 | 69,654 | 3,639,156 | 4,797,647 |
| | 1300x130 | 62,997 | 69,654 | 3,639,156 | 4,797,647 |
| | 1300x175 | 103,984 | 105,358 | 5,573,732 | 7,348,076 |

ENR "Construction Cost Index" Aug. 77 = 2611
Jan. 81 = 3400
Base: 1913 = 100

TABLE 10C CHANNEL DREDGING
SHIP DRAFT = 32 ft

| CHANNEL | SHIP SIZE | VOLUME | | COST | |
|--|-----------|---------------------------------------|---------------------------------|----------------------|----------------------|
| | | OVERBURDEN (1000 yd ³) | ROCK (1000 yd ³) | JUL. 77 (1000 \$) | JAN. 81 (1000 \$) |
| St. Marys River | 940x105 | 77,462 | 4,821 | 836,656 | 1,102,997 |
| | 1000x130 | Unknown | | 1,583,110 | 2,087,078 |
| | 1100x105 | 77,462 | 4,821 | 836,656 | 1,102,997 |
| | 1100x130 | Unknown | | 1,588,395 | 2,094,045 |
| | 1200x130 | 193,784 | 14,248 | 1,593,700 | 2,101,039 |
| | 1300x130 | 193,784 | 14,248 | 1,593,700 | 2,101,039 |
| | 1300x175 | 188,411 | 15,501 | 2,204,741 | 2,906,599 |
| Straits of Mackinac | 940x105 | 0 | 577 | 25,078 | 33,061 |
| | 1000x130 | 0 | 577 | 25,078 | 33,061 |
| | 1100x105 | 0 | 577 | 25,078 | 33,061 |
| | 1100x130 | 0 | 577 | 25,078 | 33,061 |
| | 1200x130 | 0 | 577 | 25,078 | 33,061 |
| | 1300x130 | 0 | 577 | 25,078 | 33,061 |
| | 1300x175 | 0 | 577 | 25,078 | 33,061 |
| St. Clair- Detroit R.- Pelee | 940x105 | 173,192 | 113,858 | 6,310,460 | 8,319,335 |
| | 1000x130 | Unknown | | 6,470,737 | 8,530,634 |
| | 1100x105 | 173,192 | 113,858 | 3,310,460 | 8,319,335 |
| | 1100x130 | Unknown | | 6,631,015 | 8,741,935 |
| | 1200x130 | 173,192 | 120,128 | 6,791,293 | 8,953,236 |
| | 1300x130 | 169,729 | 117,861 | 6,661,577 | 8,782,226 |
| | 1300x175 | 251,866 | 125,186 | 7,648,467 | 10,083,283 |
| Welland Canal | 940x105 | 132,846 | 26,081 | 1,316,267 | 1,735,288 |
| | 1000x130 | Not Investigated | | | |
| | 1100x105 | 132,846 | 26,081 | 1,316,267 | 1,735,288 |
| | 1100x130 | Not Investigated | | | |
| | 1200x130 | 165,845 | 30,691 | 1,596,501 | 2,104,732 |
| | 1300x130 | 165,845 | 30,691 | 1,596,501 | 2,104,732 |
| | 1300x175 | 226,014 | 43,843 | 2,226,153 | 2,934,828 |
| St. Lawrence River (costs include dike relocation 77: \$750,000 81: \$989,000) | 940x105 | 83,156 | 72,937 | 3,948,163 | 5,205,023 |
| | 1000x130 | | | | |
| | 1100x105 | 83,156 | 72,937 | 3,948,163 | 5,205,023 |
| | 1100x130 | | | | |
| | 1200x130 | 107,810 | 90,637 | 4,941,895 | 6,515,100 |
| | 1300x130 | 107,810 | 90,637 | 4,941,895 | 6,515,100 |
| | 1300x175 | 162,154 | 133,075 | 7,286,357 | 9,605,899 |

ENR "Construction Cost Index" Aug. 77 = 2611
Jan. 81 = 3400
Base: 1913 = 100
4-5

TABLE 10D CHANNEL DREDGING
SHIP DRAFT = 36 FT

| CHANNEL | SHIP SIZE | VOLUME | | COST | |
|---|-----------|---------------------------------------|---------------------------------|----------------------|----------------------|
| | | OVERBURDEN (1000 yd ³) | ROCK (1000 yd ³) | JUL. 77 (1000 \$) | JAN. 81 (1000 \$) |
| St. Marys River | 940x105 | Unknown | | 1,150,399 | 1,516,618 |
| | 1000x130 | Unknown | | 2,178,714 | 2,872,287 |
| | 1100x105 | | No Plan | | |
| | 1100x130 | Unknown | | 2,185,014 | 2,880,592 |
| | 1200x130 | 193,784 | 14,248 | 2,191,332 | 2,888,922 |
| | 1300x130 | 193,784 | 14,248 | 2,191,332 | 2,888,922 |
| | 1300x175 | 253,055 | 20,140 | 2,930,701 | 3,863,662 |
| Straits of Mackinac | 940x105 | 0 | 1,174 | 52,830 | 69,648 |
| | 1000x130 | 0 | 1,174 | 52,830 | 69,648 |
| | 1100x105 | | No Plan | | |
| | 1100x130 | 0 | 1,174 | 52,830 | 69,648 |
| | 1200x130 | 0 | 1,174 | 52,830 | 69,648 |
| | 1300x130 | 0 | 1,174 | 52,830 | 69,648 |
| | 1300x175 | 0 | 1,202 | 54,076 | 71,291 |
| St. Clair- Detroit R.- Pelee | 940x105 | Unknown | | 11,103,473 | 14,638,158 |
| | 1000x130 | Unknown | | 11,376,176 | 14,997,673 |
| | 1100x105 | | No Plan | | |
| | 1100x130 | Unknown | | 11,648,879 | 15,357,188 |
| | 1200x130 | 252,876 | 219,968 | 11,921,582 | 15,716,704 |
| | 1300x130 | 252,745 | 218,844 | 11,869,944 | 15,648,627 |
| | 1300x175 | 348,691 | 227,340 | 13,019,801 | 17,164,520 |
| Welland Canal | 940x105 | Unknown | | 1,522,449 | 2,007,106 |
| | 1000x130 | | Not Investigated | | |
| | 1100x105 | | No Plan | | |
| | 1100x130 | | Not Investigated | | |
| | 1200x130 | 178,675 | 38,123 | 1,846,458 | 2,434,260 |
| | 1300x130 | 178,675 | 38,123 | 1,846,458 | 2,434,260 |
| | 1300x175 | 243,877 | 54,308 | 2,577,086 | 3,397,477 |
| St. Lawrence River (costs include dike reduction 77: \$750,000 81: \$989,000) | 940x105 | Unknown | | 5,078,035 | 6,694,579 |
| | 1000x130 | | Not Investigated | | |
| | 1100x105 | | No Plan | | |
| | 1100x130 | | Not Investigated | | |
| | 1200x130 | 158,688 | 113,016 | 6,355,974 | 8,379,338 |
| | 1300x130 | 158,688 | 113,016 | 6,355,974 | 8,379,338 |
| | 1300x175 | 230,361 | 163,595 | 9,205,413 | 12,135,868 |

ENR "Construction Cost Index" Aug. 77 = 2611
Jan. 81 = 3400
Base: 1913 = 100

TABLE 11 WATER LEVEL COMPENSATING STRUCTURE COSTS

| LOCATION | 28 ft DRAFT | | 32 ft DRAFT | | 36 ft DRAFT | |
|---------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | 9/77 (1000\$) | 1/81 (1000\$) | 9/77 (1000\$) | 1/81 (1000\$) | 9/77 (1000\$) | 1/81 (1000\$) |
| St. Marys River | 100,000 | 129,000 | 110,000 | 141,000 | 120,000 | 154,000 |
| St. Clair River | | | | | | |
| Port Huron | 26,500 | 34,100 | 30,500 | 39,200 | 35,000 | 45,000 |
| Stag Is. | 24,000 | 30,900 | 28,000 | 36,000 | 33,000 | 42,400 |
| St. Clair | 38,000 | 48,900 | 45,000 | 57,900 | 50,000 | 64,300 |
| Marine City | 0 | 0 | 45,000 | 57,900 | 50,000 | 64,300 |
| Detroit River | | | | | | |
| Peach Is. | 50,000 | 64,300 | 57,000 | 73,300 | 68,000 | 87,400 |
| Zug Is. | 45,000 | 57,900 | 50,000 | 64,300 | 55,000 | 70,700 |
| Lower Fighting Is. & Trenton | 55,000 | 70,700 | 60,000 | 77,200 | 65,000 | 83,600 |

ENR Construction Cost Index

Sept. 77 = 2644

Jan. 81 = 3400

Base Year 1913 = 100

The lock costs were supplied by the Rock Island District as lump sum costs per lock for each vessel size, in October 1977 dollars. These costs have been updated to January 1981 dollars, using the "Construction Cost Index" which takes into account the increased cost of construction materials and common labor. A summary of the lock costs is given in Table 12.

4.3 Harbors

Not all of the harbors on the GL/SLS System were analyzed for improvements required to handle the maximum sized ship. The seventeen harbors analyzed in the "Maximum Ship Size Study" accommodate the major portion of GL/SLS iron ore, coal, and general overseas cargo traffic, and were considered representative of the entire system.

Harbor improvement scenarios were developed in the study for each ship size. These scenarios are given in Tables 13A through D. Harbor improvements include dredging the harbor and approach channels, dredging turning basins, and removing and reinstalling breakwaters. Harbor improvement quantity estimates and cost estimates were made by DeLeuw, Cather and Company [9]. The estimates on the required harbor depth to allow a specified draft were based on the theoretical amounts of squat, roll, pitch, trim and heave for each size vessel under the wind and wave conditions that could be expected for that harbor. A 2 ft safety clearance and a 1.5 ft overdredge estimate to compensate for the un-even bottom surface left by the dredging equipment were included [1].

The harbor improvement scenarios reflect, in DeLeuw Cather and Company's judgement the optimal use of each harbor for each maximum size ship. In many cases, more areas could be improved to dock smaller ships (940 and 1100 ft long) than could dock larger ships (1300 and 1500 ft long). Therefore, in these cases the harbor improvement costs for the smaller ships may be greater than for the larger ships. An obvious example of this is Toledo Harbor. As is indicated in Table 13A the harbor would be dredged to construct two new docking sites for 940 by 105 ft vessels, whereas, Table 13B indicates that a docking site for one 1100 by 105 ft vessel is already under construction (cost not included in the study). Docking sites for 1100 ft long vessels could not be constructed due to space limitations where the sites for the 940 ft vessels were planned.

TABLE 12. LOCK CONSTRUCTION COSTS (1000 \$)

| LOCK | SHIP SIZE | 25.5 FT | | 28 FT | | 32 FT | | 36 FT | |
|----------------------|------------|---------|---------------|---------|---------------|---------|---------------|---------|---------------|
| | | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 |
| S00 | 940 x 105 | 57,763 | 74,279 | 63,559 | 81,732 | 68,579 | 88,188 | 80,710 | 103,787 |
| | 1100 x 105 | 67,595 | 86,922 | 74,377 | 95,644 | 80,252 | 103,198 | 94,447 | 121,452 |
| | 1200 x 130 | 77,768 | 100,004 | 83,028 | 106,768 | 92,177 | 118,533 | 107,949 | 138,815 |
| | 1300 x 130 | 78,587 | 101,057 | 90,660 | 116,582 | 97,821 | 125,791 | 114,654 | 147,437 |
| | 1300 x 175 | 91,943 | 118,232 | 106,176 | 136,535 | 112,986 | 145,292 | 134,239 | 172,622 |
| | 1500 x 175 | 105,694 | 135,915 | 116,065 | 149,252 | 125,602 | 161,515 | 146,528 | 188,425 |
| ST. CLAIR RIVER | 940 x 105 | 0 | 0 | 48,937 | 62,930 | 52,974 | 68,121 | 64,119 | 82,453 |
| | 1100 x 105 | 50,446 | 64,870 | 57,266 | 73,640 | 61,990 | 79,715 | 75,032 | 96,486 |
| | 1200 x 130 | 58,402 | 75,101 | 65,978 | 84,843 | 71,848 | 92,392 | 85,971 | 110,553 |
| | 1300 x 130 | 61,882 | 79,576 | 69,167 | 88,944 | 76,179 | 97,961 | 91,257 | 117,350 |
| | 1300 x 175 | 73,069 | 93,962 | 81,803 | 105,193 | 89,598 | 115,217 | 99,682 | 128,184 |
| | 1500 x 175 | 78,827 | 101,366 | 89,360 | 114,911 | 97,783 | 125,742 | 116,741 | 150,121 |
| WELLAND CANAL "A" | 940 x 105 | 114,540 | 147,290 | 125,719 | 161,666 | 131,486 | 169,082 | 143,080 | 183,991 |
| | 1100 x 105 | 134,036 | 172,361 | 147,118 | 189,184 | 153,867 | 197,862 | 167,434 | 215,308 |
| | 1200 x 130 | 151,447 | 194,750 | 165,564 | 212,904 | 173,398 | 222,978 | 190,588 | 245,083 |
| | 1300 x 130 | 160,968 | 206,994 | 176,034 | 226,367 | 184,269 | 236,957 | 202,692 | 260,648 |
| | 1300 x 175 | 183,173 | 235,548 | 200,036 | 257,232 | 209,776 | 269,757 | 230,315 | 296,169 |
| | 1500 x 17 | 200,815 | 258,234 | 219,291 | 281,993 | 233,914 | 300,797 | 252,611 | 324,840 |
| WELLAND CANAL "B" | 940 x 105 | 93,031 | 119,631 | 108,634 | 139,696 | 116,356 | 149,626 | 128,879 | 165,729 |
| | 1100 x 105 | 108,866 | 139,994 | 127,125 | 163,474 | 136,161 | 175,094 | 150,816 | 193,939 |
| | 1200 x 130 | 130,148 | 167,361 | 141,416 | 181,851 | 150,165 | 193,102 | 168,433 | 216,593 |
| | 1300 x 130 | 138,383 | 177,951 | 151,076 | 194,273 | 162,135 | 208,494 | 179,263 | 230,520 |
| | 1300 x 175 | 156,409 | 201,131 | 170,084 | 218,716 | 180,002 | 231,470 | 201,652 | 259,310 |
| | 1500 x 175 | 170,989 | 219,880 | 186,948 | 240,402 | 200,535 | 247,874 | 222,452 | 286,058 |

TABLE 12 LOCK CONSTRUCTION COSTS (1000 \$)(CONTINUED)

| LOCK | SHIP SIZE | 25.5 FT | | 28 FT | | 32 FT | | 36 FT | |
|----------------------|------------|---------|------------|---------|------------|---------|------------|---------|------------|
| | | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 |
| WELLAND CANAL "C" | 940 x 105 | 99,427 | 127,856 | 109,022 | 140,195 | 116,641 | 149,992 | 129,296 | 166,266 |
| | 1100 x 105 | 116,351 | 149,619 | 127,579 | 164,058 | 136,495 | 175,523 | 151,304 | 194,566 |
| | 1200 x 130 | 130,670 | 168,033 | 142,950 | 183,824 | 152,814 | 196,508 | 169,005 | 217,329 |
| | 1300 x 130 | 142,936 | 183,806 | 152,045 | 195,519 | 162,565 | 209,047 | 179,822 | 231,239 |
| | 1300 x 175 | 157,209 | 202,160 | 170,798 | 219,634 | 183,088 | 235,438 | 203,340 | 261,481 |
| | 1500 x 175 | 171,763 | 220,875 | 187,736 | 241,415 | 201,165 | 258,684 | 222,313 | 285,879 |
| WELLAND CANAL "D" | 940 x 105 | 134,877 | 173,442 | 146,520 | 188,415 | 154,268 | 198,378 | 167,902 | 215,910 |
| | 1100 x 105 | 157,835 | 202,965 | 171,460 | 220,486 | 180,526 | 232,144 | 196,481 | 252,661 |
| | 1200 x 130 | 180,037 | 231,515 | 194,835 | 250,544 | 204,862 | 263,438 | 222,653 | 286,316 |
| | 1300 x 130 | 191,157 | 245,815 | 206,928 | 266,095 | 217,619 | 279,843 | 236,579 | 304,224 |
| | 1300 x 175 | 221,570 | 284,924 | 238,982 | 307,314 | 251,453 | 323,351 | 272,569 | 350,505 |
| | 1500 x 175 | 243,863 | 313,591 | 262,949 | 338,134 | 276,579 | 355,661 | 299,708 | 385,404 |
| WELLAND CANAL "E" | 940 x 105 | 42,747 | 54,969 | 48,095 | 61,847 | 52,111 | 67,011 | 62,657 | 80,573 |
| | 1100 x 105 | 50,023 | 64,325 | 56,281 | 72,373 | 60,981 | 78,417 | 73,322 | 94,287 |
| | 1200 x 130 | 57,605 | 74,076 | 64,933 | 83,499 | 70,173 | 90,238 | 83,971 | 107,981 |
| | 1300 x 130 | 64,207 | 82,565 | 68,786 | 88,454 | 74,329 | 95,582 | 89,028 | 114,484 |
| | 1300 x 175 | 68,316 | 87,850 | 79,373 | 102,068 | 86,319 | 111,000 | 103,232 | 132,749 |
| | 1500 x 175 | 77,337 | 99,450 | 87,099 | 112,003 | 94,628 | 121,685 | 113,081 | 145,414 |
| IROQUOIS | 940 x 105 | 43,109 | 55,435 | 48,937 | 62,930 | 52,974 | 68,121 | 64,119 | 82,453 |
| | 1100 x 105 | 50,446 | 64,870 | 57,266 | 73,640 | 61,990 | 79,715 | 75,032 | 96,486 |
| | 1200 x 130 | 58,402 | 77,101 | 65,978 | 84,843 | 71,848 | 92,392 | 85,971 | 110,553 |
| | 1300 x 130 | 61,882 | 69,576 | 69,167 | 88,944 | 76,179 | 97,961 | 91,251 | 117,350 |
| | 1300 x 175 | 73,069 | 93,962 | 81,803 | 105,193 | 89,598 | 115,217 | 99,682 | 128,184 |
| | 1500 x 175 | 78,827 | 101,366 | 89,360 | 114,911 | 97,783 | 125,742 | 116,741 | 150,121 |

TABLE 12 LOCK CONSTRUCTION COSTS (1000 \$) (CONTINUED)

| LOCK | SHIP SIZE | 25.5 FT | | 28 FT | | 32 FT | | 36 FT | |
|--------------------------------|------------|---------|------------|---------|------------|---------|------------|---------|------------|
| | | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 | 9/77 | DRAFT 1/81 |
| EISENHOWER/SNELL (combined) | 940 x 105 | 115,420 | 148,422 | 126,841 | 163,109 | 134,028 | 172,351 | 147,684 | 189,898 |
| | 1100 x 105 | 135,066 | 173,685 | 148,431 | 190,872 | 156,841 | 201,687 | 172,810 | 222,222 |
| | 1200 x 130 | 150,729 | 193,827 | 165,304 | 212,569 | 174,683 | 224,833 | 192,108 | 247,038 |
| | 1300 x 130 | 160,703 | 206,653 | 176,353 | 226,778 | 186,350 | 239,633 | 204,994 | 263,608 |
| | 1300 x 175 | 182,286 | 234,407 | 199,788 | 256,913 | 211,574 | 272,069 | 232,984 | 299,601 |
| BEAUHARNOIS (combined) | 1500 x 175 | 199,534 | 256,587 | 218,609 | 281,116 | 231,426 | 297,598 | 254,734 | 327,570 |
| | 940 x 105 | 128,174 | 164,823 | 140,281 | 180,392 | 147,596 | 189,798 | 162,548 | 209,025 |
| | 1100 x 105 | 149,991 | 192,878 | 164,159 | 211,097 | 172,719 | 222,105 | 190,216 | 244,605 |
| | 1200 x 130 | 170,959 | 219,841 | 186,099 | 239,310 | 197,446 | 253,902 | 213,063 | 273,984 |
| | 1300 x 130 | 181,445 | 233,326 | 198,068 | 254,702 | 207,770 | 267,178 | 226,840 | 291,700 |
| COTE STE. CATHERINE | 1300 x 175 | 211,090 | 271,447 | 229,682 | 295,355 | 241,223 | 310,196 | 262,843 | 337,998 |
| | 1500 x 175 | 226,450 | 291,199 | 251,727 | 323,703 | 264,268 | 339,830 | 287,863 | 370,172 |
| | 940 x 105 | 68,642 | 88,269 | 72,175 | 92,812 | 81,207 | 104,427 | 93,522 | 120,263 |
| | 1100 x 105 | 80,326 | 103,294 | 84,460 | 108,610 | 95,029 | 122,201 | 109,441 | 140,734 |
| | 1200 x 130 | 91,828 | 118,084 | 101,210 | 130,149 | 108,499 | 139,458 | 124,489 | 160,084 |
| ST. LAMBERT | 1300 x 130 | 97,522 | 125,407 | 107,517 | 138,259 | 115,256 | 148,211 | 132,332 | 170,170 |
| | 1300 x 175 | 113,063 | 145,391 | 124,612 | 160,242 | 134,044 | 172,371 | 153,503 | 197,394 |
| | 1500 x 175 | 123,821 | 159,225 | 136,346 | 175,331 | 146,554 | 188,458 | 164,935 | 212,095 |
| | 940 x 105 | 57,237 | 73,603 | 62,879 | 80,858 | 67,320 | 86,569 | 79,518 | 102,255 |
| | 1100 x 105 | 66,979 | 86,130 | 73,582 | 94,621 | 78,779 | 101,304 | 93,053 | 119,660 |
| | 1200 x 130 | 77,338 | 99,451 | 84,737 | 108,966 | 90,738 | 116,683 | 106,641 | 137,133 |
| | 1300 x 130 | 81,998 | 105,444 | 89,850 | 115,541 | 96,202 | 123,709 | 113,127 | 145,473 |
| | 1300 x 175 | 95,279 | 122,522 | 104,426 | 134,285 | 112,299 | 144,409 | 131,243 | 168,769 |
| | 1500 x 175 | 104,821 | 134,793 | 114,766 | 147,581 | 123,314 | 158,573 | 144,013 | 185,191 |

ENR "Construction Cost Index" Oct. 77 = 2675
 Jan. 81 = 3400
 Base: 1913 = 100

TABLE 13A HARBOR IMPROVEMENT SCENARIOS FOR 940' x 105' VESSELS

Duluth-Superior. Vessels would dock in the Duluth Harbor Basin. For vessels drawing 25.5 feet, deepening to 29.4 feet in the harbor and 31.3 feet in the entrance channel would be necessary. For vessels drawing 28 and 32 feet, additional dredging would be required in the harbor and in the Duluth Ship Canal and its immediate approach channel.

Milwaukee. There is space for at least four 940' x 105' vessels in the south slips of the outer harbor. The harbor has sufficient width for a turning basin and adequate entrance clearance. Deepening to 29.6 feet would be required for vessels of 25.5 foot draft in a portion of the south outer harbor and the entrance channel. Vessels of 32 foot depth would require dredging to 36.1 feet.

Calumet. 940' x 105' vessels could dock at the Transoceanic Terminal Corp. in the mouth of the Calumet River. The entrance channel with a current project depth of 28 feet would have to be deepened.

Burns Harbor, Indiana. The Indiana Port Commission Dock in Burns Harbor has adequate dimensions for 940' x 105' vessels. Additional deepening would be required for all vessel sizes under evaluation.

Detroit. There are several foreign trade general cargo and container terminals along the Detroit River. Deepening would be required for all vessels sizes under study. An additional one-half foot would be required in confined areas of the Trenton Channel.

Toledo. The 940 foot overseas vessels would dock at the Toledo Overseas Terminals Co. and Toledo-Lucas County Port Authority at the mouth of the Maumee River. The entrance channel would be widened to 800 feet and a 1400 foot turning basin would be dredged opposite the terminal.

Cleveland. At least one 940 foot vessel could dock at the Port of Cleveland, east of the mouth of the Cuyahoga River, entering the harbor from the main Lake Approach. Dredging would be required for all vessel sizes under study.

Buffalo. Ships would dock at the Buffalo Overseas Terminal adjacent to the outer harbor. Vessels would enter and exit the outer harbor by the north entrance channel which would be widened at the Buffalo River entrance channel to provide space for turning. Dredging would be required in the approach channel, the north portion of the outer harbor, and where a 1400 foot turning basin would be located in the south portion of the outer harbor.

Connecting Channels. St. Mary's River. Dredging would be necessary for vessel drafts of 28 and 32 feet.

St. of Mackinac. New work dredging would be required for 28 and 32 foot drafts. Additional maintenance dredging would not be required.

St. Clair and Detroit Rivers. Deepening of channels would be necessary for vessels drawing 28 or 32 feet.

Detroit East Outer Channel to Toledo Harbor Approach. Dredging would be required to create and maintain an 800 foot wide channel to 31.3 feet for vessels of 25.5 foot draft and to correspondingly greater depths for vessels of greater drafts.

Pelee Passage. Dredging would be required to same depths as above. Because this is the central Lake Erie passage, a 2000 foot wide channel would be maintained.

Welland Canal. Widening and deepening of the Welland Canal would be required for all alternative vessel sizes and drafts under study.

St. Lawrence River. Widening and deepening of some reaches of the St. Lawrence River would be necessary for all vessel scenarios being evaluated. Unless limited by lock or bridge approaches or by constricting land masses, channels would be widened to 800 feet for vessels of 105 foot beam.

TABLE 13B HARBOR IMPROVEMENT SCENARIOS FOR 1100' x 105' VESSEL

Duluth-Superior. Vessels entering through the Duluth Ship Canal would be able to dock at the Duluth, Misabe, and Iron Range Railway ore docks and the new Superior Midwest Energy (coal) Terminal on either side of St. Louis Bay. A 1650 foot turning basin would be dredged in the cross channel in St. Louis Bay. Vessels could also dock at the Burlington-Northern ore docks in the Superior Harbor Basin using the Superior Entry. A turning basin would be dredged in the Superior Harbor Basin. Both approach channels would also need additional dredging.

Two Harbors. The harbor has dockage space for two 1100 foot vessels. About 400 feet of the east breakwater would be removed to make room for a 1650 foot turning basin. A new breakwater extension 450 feet in length would be constructed. Areas near the east breakwater would need additional dredging. Harbor areas in proximate to the ore docks would need dredging for drafts greater than 25.5 feet.

Presque Isle. For 1100' x 105' x 25.5' draft vessels, a small additional area would be dredged to provide a turning basin within the area protected by the U.S. breakwater. The entire harbor would need deepening for greater drafts.

Calumet. An 1100 foot ship would be able to dock along U.S. Steel property between the North Slip and the mouth of the Calumet River. This area would have to be dredged from the current 26 foot project depth for all draft alternatives being evaluated, as would the entrance channel currently having a 28 foot project depth.

Indiana. Two vessels could dock along the northwest shoreline of Youngstown Sheet and Tube Co., property to the east of the approach channel to Indiana Harbor. Two breakwaters, 1800 and 2000 feet in length, would be constructed to shelter the new harbor. A 1650 foot turning basin would be dredged in the sheltered area.

Gary. At least one 1100' x 105' vessel could dock on the U.S. Steel Co., slip in Gary Harbor. A 1650 foot turning basin would be dredged in the outer harbor.

Burns. A 1650 foot turning basin would be dredged within the existing breakwaters. The project depth of 28 feet would have to be deepened for all vessel alternatives under study.

Detroit. Approaches would be dredged to the docks of the National Steel Co. on the Detroit River and to the Detroit Edison Co. in the mouth of the Rouge River. The Trenton Channel would be widened to 525 feet past the BASF Wyandot Corp dock. South of Grassy Island a new channel would be dredged back to Fighting Island Channel, and the Trenton Channel would be widened to 315 feet so that 1100 foot vessels could proceed to the McLouth Steel Corp. To the south of the McLouth ore dock a 1650 foot turning basin would be dredged. Even under the alternative scenarios for larger vessels, the enlarged Trenton Channel south of Grassy Island would be limited to 1100' x 105' vessels.

Toledo. Bulk carriers would dock along a site presently being filled just northeast of Harbor View Beach. A 1650 foot turning basin would be dredged north of the docks assumed to be constructed, across the entrance channel to the east of the existing diked disposal area. The entrance and approach channel would be widened to 800 feet.

Sandusky. To accommodate 1100 foot vessels at the Norfolk and Western Railway coal dock and Lower Lakes Dock Co., a new 1650 foot turning basin would be dredged in the proximity of the existing turning basin in the southwest corner of the harbor. The south 400 feet of the spur dike and west 1250 feet of the rock dike would be removed. A new 800 foot tie in to the rock dike would be constructed. Deepening below current project depths would be required for all vessel drafts under study. A small portion of the U.S. project adjacent to the Lower Lakes dock would be abandoned to provide space for docked vessels.

Lorrain. Dockage space is adequate for two 1100 foot vessels. A 1650 foot turning basin would be dredged within the area protected by the existing breakwaters.

Cleveland. Vessels would unload at the Ohio and Western Pennsylvania/Penn Central dock in the west basin of the harbor. The east and west interior stub breakwater would be partially removed to provide space for a 1650 foot turning basin. Two additional breakwaters would be constructed outside of the West Channel Entrance. Each breakwater would be about 630 feet long in 27 to 32 feet of water.

Ashtabula. An 1100 foot vessel would unload at the Pinney Dock on the east side of the harbor. A 1650 foot turning basin would be dredged.

Conneaut. There would be space for 1100' x 105' bulk carriers to dock at the mouth of the Conneaut River and along a pier extension on the east side of the harbor being planned by U.S. Steel. Additional dredging would be performed to create a 1650 foot turning basin within the existing breakwaters.

Buffalo. It is assumed that ore dock facilities would be constructed along the outer harbor shoreline; there is space alongside Diked Disposal Area No. 2, along an area south of Municipal Pier, and adjacent to the Buffalo Small Boat Harbor. The north channel entrance would be dredged wider to permit 1100 foot vessels to turn into and out of the outer harbor, and a 1650 foot turning basin for ships to reverse direction would be dredged in the southern portion of the outer harbor.

Connecting Channels. For St. Mary's River, St. of Mackinac, St. Clair and Detroit Rivers, Detroit East Outer Channel to Toledo Harbor Approach, Pelee Passage, and Welland Canal: same as text for 940' x 105' vessel.

St. Lawrence River. Same as text for 940' x 105' vessel.

TABLE 13C HARBOR IMPROVEMENT SCENARIOS FOR 1200' AND
1300' x 130' VESSELS

- Duluth-Superior. The 1200 and 1300 foot vessels would load iron ore and coal at the docks in St. Louis Bay and Superior Harbor Basin. Additional areas would be dredged to provide maneuvering space in the Duluth Harbor and East Gate Basins, and two turning basins 1950 feet in diameter would be dredged (one in the Superior Harbor Basin; the other in the St. Louis Bay cross channels).
- Two Harbors. Two 1200 or 1300 foot vessels could dock at Two Harbors. About 900 feet of the east breakwater would have to be removed for a 1950 foot turning basin. A new breakwater extension 1050 feet in length would be constructed.
- Presque Isle. Dredging would be required to form a 1950 foot turning basin in the area protected by the existing breakwater.
- Calumet. The area between the North Slip and the mouth of the Calumet River would be dredged to provide dockage space for the larger vessels. The area within the existing 28 foot project would also need deepening.
- Indiana. Additional breakwaters outside of the present harbor would be constructed as in the 1100 foot alternative. For 1200 and 1300 foot ships, a 1950 foot turning basin would be dredged within the protected area.
- Gary. There is sufficient clearance for a 1200 or 1300 foot vessel to unload in the existing large slip. A turning basin 1950 feet in diameter would be dredged within the existing breakwater enclosure.
- Burns. There is room within the existing harbor for dredging the required 1950 foot turning basin. Project depths would also have to be deepened.
- Detroit. The improvements necessary for 1200 or 1300 foot vessels are identical to those described under the 1100 foot vessel scenario.
- Toledo. Ships of 130 foot beam would require the entrance channel to Toledo Harbor to be widened to 990 feet for two-way passage. A turning basin 1950 feet in diameter would also be dredged to the east of the existing diked disposal area.

Sandusky. Vessels up to 1300 feet long could dock at the Norfolk and Western Railway coal dock and the slip of the Lower Lakes Dock Co. The Bay Channel and Mosely Channel would be widened to 400 feet. The entire spur dike and approximately 1600 feet of the western rock dike would be removed. A 1950 foot turning basin would be dredged, and a new dike 1800 feet in length would be built to tie into the remaining portion of the rock dike.

Lorain. For ships up to 1300 feet in length, about 1000 feet of the west breakwater would have to be removed. It would be replaced by a curving breakwater some 2,300 feet in length to provide for a 1950 foot turning basin.

Cleveland. Improvements to accommodate 1200 or 1300 foot ships in Cleveland Harbor are the same as those for 1100 foot ships, except that the east and west interior stub breakwaters would be almost completely removed, and a larger 1950 foot turning basin would be dredged.

Ashtabula. Vessels up to 1300 feet in length could unload at the Pinney Dock. Improvements required are the same as for 1100 foot vessels except for a larger 1950 foot turning basin.

Conneaut. Improvements would be the same as for the 1100 foot vessels, except for a 1950 foot turning basin.

TABLE 13D HARBOR IMPROVEMENT SCENARIOS FOR 1500' x 175' VESSEL

Duluth-Superior. For the 175 foot wide vessel, one incremental improvement would be necessary. The Burlington-Northern Railway swing bridge over the South Channel in St. Louis Bay would be converted to a larger movable span of at least 250 feet.

Two Harbors, Presque Isle, Calumet, Indiana Harbors. No incremental improvements.

Gary. No incremental improvements. A 175 foot beam ship could dock in the existing 250 foot wide slip.

Burns, Detroit Harbor. No incremental improvements.

Toledo. The approach and entrance channels would be widened to 1330 feet for two-way passage of 175 foot beam vessels.

Sandusky. In addition to the improvements made for the 130 foot beam vessels, the Bay and Mosley Channels would have to be widened to 525 feet.

Lorain, Cleveland, Ashtabula, Conneaut, and Buffalo Harbors. No incremental improvements except for widening of approach channels into the lake where such channels are necessary for deeper drafts.

Connecting Channels. For the St. Mary's River, Strait of Mackinac, St. Clair and Detroit Rivers, Detroit East Outer Channel to Toledo Harbor Approach, and Welland Canal: same as text of 940' x 105' vessel except that two way-channel clearance would generally be 1330 feet (e.g. Detroit East Outer Channel to Toledo Harbor Approach). The Pelee Passage would have a 2000 foot channel width.

St. Lawrence River. Same as test for 940' x 105' vessel, except channels would be widened to 1330 feet where practicable.

Buffalo. For 1300 foot vessels, the short breakwater between the North Breakwater and New West Breakwater would be removed to provide full clearance for a 1950 foot turning basin. For 1200 foot vessels the breakwater (and its lights) would remain in place. For all ships of 130 foot beam, the approach channel would be widened to 990 feet for two-way traffic.

Connecting Channels. For the St. Mary's River, Strait of Mackinac, St. Clair and Detroit Rivers, Detroit East Outer Channel to Toledo Harbor Approach, and Welland Canal: Same as text for 940' x 105' vessel, except that two-way channel clearance would generally be 990 feet (e.g. Detroit East Outer Channel to Toledo Harbor Approach). The Pelee Passage would have a width of 2000 feet.

St. Lawrence River. Same as text for 940' x 105' vessel except that channels would be widened to 990 feet where practicable.

The harbor improvement cost estimates from the "Maximum Ship Size Study" were given in September 1977 dollars. These figures were updated to January 1981 dollars using the "Construction Cost Index". A breakdown of the improvement costs by harbor and ship size is given in Tables 14A through E. The cost given in each table is independent of those in the other tables. These costs are not incremental from the 940 x 105 ft ship size.

4.4 Bridges and Tunnels

Improvements to some of the bridges and tunnels along the GL/SLS connecting channels are required to permit safe passage of larger ships. The required bridge span for safe passage is dictated by ship beam. No head room restrictions for bridges were cited in the 1977 study. Tunnel size criteria are beam and draft dependent. Listed in Table 15 are the bridges, and in Table 16 the tunnels, which may require modification to accommodate the larger ships which are under consideration. Bridges and tunnels not listed in the tables will not require modification. Also given in Tables 15 and 16 are the estimated modification costs from the "Maximum Ship Size Study" in January 1977 dollars, and the updated costs in January 1981 dollars. These cost updates were obtained using the "Building Cost Index" from *Engineering News Record*.

4.5 Aids to Navigation

The "Maximum Ship Size Study" estimates that aids to navigation will cost approximately 1% of the total federal construction capital costs. The federal construction capital costs are the costs of harbor and channel dredging, lock construction, and bridge and tunnel construction. Since the federal construction capital costs have been updated already, and since it is assumed that the costs of aids to navigation have not increased at a greater rate than these costs, the 1% figure was also used to determine the updated cost of aids to navigation.

4.6 Real Estate Costs

No estimate was made in the "Maximum Ship Size Study" of the amount of real estate that would have to be purchased as part of the system improvements. Rather, an estimate of real estate costs was made by using 2% of the federal construction capital costs. Since there is no additional information on this topic, 2% of the updated federal construction capital costs was used to estimate the updated real estate costs in this report.

TABLE 14A HARBOR DREDGING

Ship Size = 940 x 105

| HARBOR | VOLUME OVERBURDEN (1000 yd ³) | ROCK (1000 yd ³) | BREAKWATER REMOVAL (FT) | 9/77 (1000 \$) | COST 1/81 (1000 \$) |
|----------------------|---|---------------------------------|-------------------------------|-------------------|---------------------------|
| SHIP DRAFT = 25.5 FT | | | | | |
| Buffalo | 6,207 | 0 | 0 | 20,173 | 25,941 |
| Burns Harbor | 384 | 0 | 0 | 1,200 | 1,543 |
| Cleveland | 50 | 0 | 0 | 450 | 579 |
| Milwaukee | 924 | 0 | 0 | 6,100 | 7,844 |
| Toledo | 28,318 | 0 | 0 | 131,850 | 169,550 |
| SHIP DRAFT = 28 FT | | | | | |
| Buffalo | 9,977 | 0 | 0 | 32,425 | 41,696 |
| Burns Harbor | 1,140 | 0 | 0 | 3,380 | 4,346 |
| Calumet | 13,522 | 0 | 0 | 54,087 | 69,552 |
| Cleveland | 577 | 0 | 0 | 4,152 | 5,339 |
| Detroit | 401 | 0 | 0 | 1,607 | 2,066 |
| Duluth-Superior | 3,630 | 0 | 0 | 38,000 | 48,865 |
| Milwaukee | 1,757 | 0 | 0 | 10,800 | 13,888 |
| Toledo | 35,339 | 0 | 0 | 164,480 | 211,510 |
| SHIP DRAFT = 32 FT | | | | | |
| Buffalo | 25,139 | 0 | 0 | 81,703 | 105,064 |
| Burns Harbor | 2,361 | 0 | 0 | 6,830 | 8,783 |
| Calumet | 30,610 | 0 | 0 | 122,443 | 157,453 |
| Cleveland | 1,732 | 0 | 0 | 12,065 | 15,515 |
| Detroit | 878 | 0 | 0 | 3,513 | 4,517 |
| Duluth-Superior | 8,257 | 0 | 0 | 58,500 | 75,227 |
| Milwaukee | 3,090 | 0 | 0 | 18,300 | 23,533 |
| Toledo | 46,727 | 0 | 0 | 245,930 | 316,249 |
| SHIP DRAFT = 36 FT | | | | | |
| Buffalo | 37,624 | 0 | 0 | 122,277 | 157,240 |
| Burns Harbor | 3,671 | 0 | 0 | 10,500 | 13,502 |
| Calumet | 46,959 | 0 | 0 | 187,834 | 241,541 |
| Cleveland | 2,887 | 0 | 0 | 20,650 | 26,554 |
| Detroit | 1,130 | 0 | 0 | 4,520 | 5,812 |
| Duluth-Superior | 11,104 | 0 | 0 | 78,500 | 100,946 |
| Milwaukee | 4,424 | 0 | 0 | 25,800 | 33,177 |
| Toledo | 58,111 | 0 | 0 | 584,780 | 751,986 |

ENR "Construction Cost Index" Sept. 77 = 2644
 Jan. 81 = 3400
 Base: 1913 = 100

TABLE 14B HARBOR DREDGING

Ship Size = 1100 x 105

| HARBOR | VOLUME OVERBURDEN (1000 yd ³) | ROCK (1000 yd ³) | BREAKWATER REMOVAL (FT) | COST 9/77 (1000 \$) | 1/81 (1000 \$) |
|----------------------|---|---------------------------------|-------------------------------|---------------------------|-------------------|
| SHIP DRAFT = 25.5 FT | | | | | |
| Ashtabula | 271 | 0 | 0 | 2,700 | 3,472 |
| Buffalo | 3,788 | 0 | 0 | 10,930 | 26,915 |
| Cleveland | 882 | 0 | 1,300 | 9,530 | 12,255 |
| Conneaut | 168 | 0 | 0 | 2,330 | 2,996 |
| Detroit | | 0 | 0 | 75,440 | 97,011 |
| Lorain | 911 | 0 | 0 | 8,630 | 11,098 |
| Sandusky | 3,595 | 0 | 1,650 | 80,930 | 104,070 |
| SHIP DRAFT = 28 FT | | | | | |
| Ashtabula | 542 | 0 | 0 | 6,380 | 8,204 |
| Buffalo | 6,231 | 0 | 0 | 37,378 | 48,066 |
| Burns Harbor | 583 | 0 | 0 | 1,800 | 2,315 |
| Calumet | | 0 | 0 | 63,294 | 81,392 |
| Cleveland | 1,532 | 0 | 1,300 | 13,682 | 17,594 |
| Conneaut | 566 | 0 | 0 | 3,980 | 5,118 |
| Detroit | | 0 | 0 | 104,330 | 134,161 |
| Duluth-Superior | 7,941 | 0 | 0 | 95,438 | 122,727 |
| Gary | 1,083 | 40 | 0 | 9,980 | 12,834 |
| Indiana | 2,704 | 0 | 3,800 | 40,900 | 52,595 |
| Lorain | 1,407 | 0 | 0 | 15,376 | 19,772 |
| Presque Isle | 196 | 0 | 0 | 1,580 | 2,032 |
| Sandusky | 4,839 | 0 | 1,650 | 118,306 | 152,133 |
| Toledo | 27,584 | 0 | 0 | 128,480 | 165,216 |
| Two Harbors | 90 | 0 | 400 | 6,100 | 7,844 |
| SHIP DRAFT = 32 FT | | | | | |
| Ashtabula | 975 | 0 | 0 | 13,661 | 17,567 |
| Buffalo | 10,141 | 0 | 0 | 93,289 | 119,963 |
| Burns Harbor | 1,277 | 0 | 0 | 3,750 | 4,822 |
| Calumet | | 0 | 0 | 143,285 | 184,255 |
| Cleveland | 3,799 | 0 | 1,300 | 27,895 | 35,871 |
| Conneaut | 1,284 | 0 | 0 | 13,503 | 17,364 |
| Detroit | | 0 | 0 | 163,330 | 210,031 |
| Duluth | 11,171 | 68 | 0 | 139,805 | 179,780 |
| Gary | 609 | 1,345 | 0 | 23,400 | 30,091 |
| Indiana | 6,412 | 0 | 3,800 | 97,500 | 125,378 |

TABLE 14B HARBOR DREDGING (Continued)

Ship Size = 1100 x 105

| <u>HARBOR</u> | <u>VOLUME</u> | | <u>BREAKWATER</u> | <u>COST</u> | |
|---------------------------|------------------------------|------------------------------|-------------------|------------------|------------------|
| | <u>OVERBURDEN</u> | <u>ROCK</u> | <u>REMOVAL</u> | <u>9/77</u> | <u>1/81</u> |
| | <u>(1000 yd³)</u> | <u>(1000³yd)</u> | <u>(FT)</u> | <u>(1000 \$)</u> | <u>(1000 \$)</u> |
| <u>SHIP DRAFT = 32 FT</u> | | | | | |
| Lorain | 2,199 | 0 | 0 | 26,858 | 34,538 |
| Presque Isle | 657 | 0 | 0 | 6,450 | 8,294 |
| Sandusky | 7,231 | 0 | 1,650 | 183,069 | 235,414 |
| Toledo | 38,004 | 0 | 0 | 209,030 | 268,798 |
| Two Harbors | 238 | 0 | 400 | 13,700 | 17,617 |

SHIP DRAFT = 36 FT

NO PLAN

ENR "Construction Cost Index" Sept. 77 = 2644
 Jan. 81 = 3400
 Base: 1913 = 100

TABLE 14C HARBOR DREDGING

Ship Size = 1200 x 130

| <u>HARBOR</u> | <u>VOLUME</u> | | <u>BREAKWATER</u> | | <u>COST</u> |
|-----------------------------|-------------------------|-------------------------|-------------------|-------------|-------------|
| | <u>OVERBURDEN</u> | <u>ROCK</u> | <u>REMOVAL</u> | <u>9/77</u> | <u>1/81</u> |
| | (1000 yd ³) | (1000 yd ³) | (FT) | (1000 \$) | (1000 \$) |
| <u>SHIP DRAFT = 25.5 FT</u> | | | | | |
| Ashtabula | 486 | 0 | 0 | 3,560 | 4,578 |
| Buffalo | 5,045 | 0 | 0 | 23,400 | 30,091 |
| Burns Harbor | 195 | 0 | 0 | 6,000 | 7,716 |
| Calumet | 4,517 | 0 | 0 | 18,068 | 23,234 |
| Cleveland | 818 | 0 | 1,300 | 9,790 | 12,589 |
| Conneaut | 285 | 0 | 0 | 3,230 | 4,154 |
| Detroit | 2,313 | 0 | 0 | 9,250 | 11,895 |
| Duluth-Superior | 11,732 | 0 | 0 | 84,347 | 108,464 |
| Gary | 716 | 42 | 0 | 5,800 | 7,458 |
| Indiana | 561 | 0 | 3,800 | 10,140 | 13,039 |
| Lorain | 851 | 0 | 1,000 | 13,840 | 17,797 |
| Presque Isle | 98 | 0 | 0 | 790 | 1,016 |
| Sandusky | 5,310 | 0 | 1,600 | 92,550 | 119,013 |
| Toledo | 30,239 | 0 | 0 | 125,360 | 161,204 |
| Two Harbors | 37 | 0 | 900 | 4,000 | 5,144 |

SHIP DRAFT = 28 FT

| | | | | | |
|-----------------|--------|-----|-------|---------|---------|
| Ashtabula | 867 | 0 | 0 | 10,133 | 13,030 |
| Buffalo | 7,468 | 0 | 0 | 37,848 | 48,670 |
| Burns Harbor | 606 | 0 | 0 | 1,910 | 2,456 |
| Calumet | 21,372 | 0 | 0 | 85,488 | 109,932 |
| Cleveland | 1,628 | 0 | 1,300 | 14,681 | 18,879 |
| Conneaut | 693 | 0 | 0 | 5,580 | 7,175 |
| Detroit | 3,403 | 0 | 0 | 13,610 | 17,502 |
| Duluth-Superior | 15,537 | 0 | 0 | 108,869 | 139,998 |
| Gary | 666 | 266 | 0 | 9,200 | 11,831 |
| Indiana | 1,838 | 0 | 3,800 | 25,020 | 32,174 |
| Lorain | 1,359 | 0 | 1,000 | 22,783 | 29,297 |
| Presque Isle | 167 | 0 | 0 | 1,510 | 1,942 |
| Sandusky | 6,685 | 0 | 1,600 | 134,270 | 172,662 |
| Toledo | 37,487 | 0 | 0 | 158,700 | 204,077 |
| Two Harbors | 96 | 0 | 900 | 7,000 | 9,002 |

SHIP DRAFT = 32 FT

| | | | | | |
|--------------|--------|-----|---|--------|---------|
| Ashtabula | 1,475 | 0 | 0 | 16,950 | 21,797 |
| Buffalo | 10,606 | 785 | 0 | 94,573 | 121,614 |
| Burns Harbor | 1,278 | 0 | 0 | 3,900 | 5,015 |

TABLE 14C HARBOR DREDGING (Continued)

Ship Size = 1200 x 130

| <u>HARBOR</u> | <u>VOLUME</u> | | <u>BREAKWATER REMOVAL</u> (FT) | <u>COST</u> | |
|---------------------------|--|--|---------------------------------------|--------------------------|--------------------------|
| | <u>OVERBURDEN</u> (1000 yd ³) | <u>ROCK</u> (1000 yd ³) | | <u>9/77</u> (1000 \$) | <u>1/81</u> (1000 \$) |
| <u>SHIP DRAFT = 32 FT</u> | | | | | |
| Calumet | 48,382 | 0 | 0 | 193,528 | 248,864 |
| Cleveland | 3,756 | 0 | 1,300 | 29,324 | 37,709 |
| Conneaut | 1,445 | 0 | 0 | 15,387 | 19,787 |
| Detroit | 5,200 | 0 | 0 | 20,800 | 26,747 |
| Duluth-Superior | 21,763 | 63 | 0 | 155,574 | 200,057 |
| Gary | 483 | 1,170 | 0 | 21,900 | 28,162 |
| Indiana | 4,709 | 0 | 3,800 | 64,040 | 82,351 |
| Lorain | 2,169 | 0 | 1,000 | 37,943 | 48,792 |
| Presque Isle | 690 | 0 | 0 | 6,980 | 8,976 |
| Sandusky | 9,277 | 0 | 1,600 | 206,665 | 265,757 |
| Toledo | 48,795 | 0 | 0 | 250,540 | 322,177 |
| Two Harbors | 292 | 0 | 900 | 16,300 | 20,961 |

SHIP DRAFT = 36 FT

| | | | | | |
|-----------------|--------|-------|-------|---------|---------|
| Ashtabula | 2,083 | 0 | 0 | 37,288 | 47,950 |
| Buffalo | 13,131 | 1,966 | 0 | 187,648 | 241,302 |
| Burns Harbor | 2,031 | 0 | 0 | 6,150 | 7,908 |
| Calumet | 74,220 | 0 | 0 | 296,881 | 381,768 |
| Cleveland | 5,928 | 0 | 1,300 | 45,160 | 58,073 |
| Conneaut | 2,197 | 0 | 0 | 28,790 | 37,022 |
| Detroit | 6,883 | 0 | 0 | 27,530 | 35,402 |
| Duluth-Superior | 27,049 | 1,071 | 0 | 206,053 | 264,970 |
| Gary | 528 | 1,876 | 0 | 49,800 | 64,039 |
| Indiana | 7,589 | 0 | 3,800 | 140,840 | 181,110 |
| Lorain | 2,981 | 0 | 1,000 | 67,813 | 87,203 |
| Presque Isle | 1,240 | 0 | 0 | 15,830 | 20,356 |
| Sandusky | 11,835 | 0 | 1,600 | 352,621 | 453,446 |
| Toledo | 60,390 | 0 | 0 | 589,500 | 758,056 |
| Two Harbors | 524 | 0 | 900 | 29,900 | 38,449 |

ENR "Construction Cost Index" Sept. 77 = 2644
 Jan. 81 = 3400
 Base: 1913 = 100

TABLE 14D HARBOR DREDGING

Ship Size = 1300 x 130

| HARBOR | VOLUME OVERBURDEN (1000 yd) | ROCK (1000 yd) | BREAKWATER REMOVAL (FT) | 9/77 (1000 \$) | COST 1/81 (1000 \$) |
|----------------------|------------------------------------|--------------------|-------------------------------|-------------------|---------------------------|
| SHIP DRAFT = 25.5 FT | | | | | |
| Ashtabula | 527 | 0 | 0 | 4,430 | 5,697 |
| Buffalo | 5,465 | 0 | 0 | 23,810 | 30,618 |
| Burns Harbor | 211 | 0 | 0 | 6,750 | 8,680 |
| Calumet | 4,894 | 0 | 0 | 19,574 | 25,171 |
| Cleveland | 886 | 0 | 1,300 | 10,050 | 12,924 |
| Conneaut | 309 | 0 | 0 | 4,130 | 5,311 |
| Detroit | 2,438 | 0 | 0 | 9,750 | 12,538 |
| Duluth-Superior | 12,710 | 0 | 0 | 91,411 | 117,548 |
| Gary | 776 | 45 | 0 | 5,630 | 7,240 |
| Indiana | 608 | 0 | 3,800 | 10,990 | 14,132 |
| Lorain | 922 | 0 | 1,000 | 19,050 | 24,497 |
| Presque Isle | 106 | 0 | 0 | 900 | 1,157 |
| Sandusky | 5,752 | 0 | 1,600 | 104,180 | 133,968 |
| Toledo | 32,759 | 0 | 0 | 152,480 | 196,079 |
| Two Harbors | 40 | 0 | 900 | 4,800 | 6,172 |
| SHIP DRAFT = 28 FT | | | | | |
| Ashtabula | 939 | 0 | 0 | 9,380 | 12,062 |
| Buffalo | 8,090 | 0 | 0 | 38,298 | 49,249 |
| Burns Harbor | 656 | 0 | 0 | 2,000 | 2,572 |
| Calumet | 23,153 | 0 | 0 | 92,612 | 119,093 |
| Cleveland | 1,764 | 0 | 1,300 | 15,581 | 20,036 |
| Conneaut | 751 | 0 | 0 | 7,200 | 9,259 |
| Detroit | 3,585 | 0 | 0 | 14,340 | 18,440 |
| Duluth-Superior | 16,832 | 0 | 0 | 120,578 | 155,055 |
| Gary | 721 | 288 | 0 | 8,480 | 10,905 |
| Indiana | 1,991 | 0 | 3,800 | 27,110 | 34,862 |
| Lorain | 1,472 | 0 | 1,000 | 30,023 | 38,607 |
| Presque Isle | 181 | 0 | 0 | 1,430 | 1,839 |
| Sandusky | 7,242 | 0 | 1,600 | 149,870 | 192,722 |
| Toledo | 40,611 | 0 | 0 | 188,930 | 242,951 |
| Two Harbors | 104 | 0 | 900 | 8,100 | 10,416 |
| SHIP DRAFT = 32 FT | | | | | |
| Ashtabula | 1,598 | 0 | 0 | 20,070 | 25,802 |
| Buffalo | 11,490 | 850 | 0 | 94,663 | 123,016 |
| Burns Harbor | 1,385 | 0 | 0 | 4,050 | 5,208 |
| Calumet | 52,414 | 0 | 0 | 209,656 | 269,603 |

TABLE 14D HARBOR DREDGING (Continued)

Ship Size = 1300 x 130

| <u>HARBOR</u> | <u>VOLUME</u> | | <u>BREAKWATER REMOVAL (FT)</u> | <u>COST</u> | |
|-----------------|---|---------------------------------------|--|---------------------------|---------------------------|
| | <u>OVERBURDEN (1000 yd³)</u> | <u>ROCK (1000 yd³)</u> | | <u>9/77 (1000 \$)</u> | <u>1/81 (1000 \$)</u> |
| Cleveland | 4,069 | 0 | 1,300 | 30,334 | 39,007 |
| Conneaut | 1,565 | 0 | 0 | 17,147 | 22,050 |
| Detroit | 5,478 | 0 | 0 | 21,910 | 28,175 |
| Duluth-Superior | 23,577 | 68 | 0 | 169,276 | 217,677 |
| Gary | 523 | 1,267 | 0 | 20,550 | 26,426 |
| Indiana | 5,101 | 0 | 3,800 | 69,380 | 89,218 |
| Lorain | 2,350 | 0 | 1,000 | 48,403 | 62,243 |
| Presque Isle | 748 | 0 | 0 | 7,500 | 9,644 |
| Sandusky | 10,050 | 0 | 1,600 | 228,565 | 293,919 |
| Toledo | 52,861 | 0 | 0 | 292,050 | 375,556 |
| Two Harbors | 316 | 0 | 900 | 19,000 | 24,433 |

SHIP DRAFT = 36 FT

| | | | | | |
|-----------------|--------|-------|-------|---------|---------|
| Ashtabula | 2,257 | 0 | 0 | 39,988 | 51,422 |
| Buffalo | 14,225 | 2,130 | 0 | 195,718 | 251,680 |
| Burns Harbor | 2,200 | 0 | 0 | 6,380 | 8,204 |
| Calumet | 80,433 | 0 | 0 | 321,730 | 413,722 |
| Cleveland | 6,422 | 0 | 1,300 | 46,280 | 59,513 |
| Conneaut | 2,380 | 0 | 0 | 31,170 | 40,082 |
| Detroit | 7,258 | 0 | 0 | 29,030 | 37,331 |
| Duluth-Superior | 29,303 | 1,160 | 0 | 222,192 | 285,723 |
| Gary | 572 | 2,032 | 0 | 49,280 | 63,371 |
| Indiana | 8,221 | 0 | 3,800 | 152,580 | 196,207 |
| Lorain | 3,229 | 0 | 1,000 | 84,463 | 108,614 |
| Presque Isle | 1,343 | 0 | 0 | 17,100 | 21,989 |
| Sandusky | 12,821 | 0 | 1,600 | 383,001 | 492,513 |
| Toledo | 65,423 | 0 | 0 | 666,380 | 856,918 |
| Two Harbors | 568 | 0 | 900 | 31,900 | 41,021 |

ENR "Construction Cost Index" Sept. 77 = 2644
 Jan. 81 = 3400
 Base: 1913 = 100

TABLE 14E HARBOR DREDGING

Ship Size = 1300 x 175

| <u>HARBOR</u> | <u>VOLUME</u> | | <u>BREAKWATER</u> | | <u>COST</u> |
|-----------------------------|------------------------------|------------------------------|-------------------|------------------|------------------|
| | <u>OVERBURDEN</u> | <u>ROCK</u> | <u>REMOVAL</u> | <u>9/77</u> | <u>1/81</u> |
| | <u>(1000 yd³)</u> | <u>(1000 yd³)</u> | <u>(FT)</u> | <u>(1000 \$)</u> | <u>(1000 \$)</u> |
| <u>SHIP DRAFT = 25.5 FT</u> | | | | | |
| Ashtabula | 527 | 0 | 0 | 4,430 | 5,697 |
| Buffalo | 7,546 | 0 | 0 | 24,524 | 31,536 |
| Burns Harbor | 211 | 0 | 0 | 6,750 | 8,680 |
| Calumet | 6,588 | 0 | 0 | 26,350 | 33,884 |
| Cleveland | 886 | 0 | 1,300 | 10,050 | 12,924 |
| Conneaut | 309 | 0 | 0 | 4,130 | 5,311 |
| Detroit | 2,890 | 0 | 0 | 11,560 | 14,865 |
| Duluth-Superior | 13,668 | 0 | 0 | 95,677 | 123,034 |
| Gary | 776 | 45 | 0 | 5,630 | 7,240 |
| Indiana | 819 | 0 | 3,800 | 14,800 | 19,032 |
| Lorain | 922 | 0 | 1,000 | 19,050 | 24,497 |
| Presque Isle | 106 | 0 | 0 | 900 | 1,157 |
| Sandusky | 5,752 | 0 | 1,600 | 104,180 | 133,968 |
| Toledo | 32,759 | 0 | 0 | 152,480 | 196,079 |
| Two Harbors | 40 | 0 | 900 | 4,800 | 6,172 |
| <u>SHIP DRAFT = 28 FT</u> | | | | | |
| Ashtabula | 939 | 0 | 0 | 9,380 | 12,062 |
| Buffalo | 12,141 | 0 | 0 | 39,457 | 50,739 |
| Burns Harbor | 656 | 0 | 0 | 2,000 | 2,572 |
| Calumet | 31,168 | 0 | 0 | 124,670 | 160,317 |
| Cleveland | 1,389 | 0 | 1,300 | 15,753 | 20,257 |
| Conneaut | 751 | 0 | 0 | 7,200 | 9,259 |
| Detroit | 3,998 | 0 | 0 | 15,990 | 20,562 |
| Duluth-Superior | 17,895 | 0 | 0 | 125,268 | 161,086 |
| Gary | 721 | 288 | 0 | 8,480 | 10,905 |
| Indiana | 2,028 | 0 | 3,800 | 36,500 | 46,936 |
| Lorain | 1,469 | 0 | 1,000 | 30,344 | 39,020 |
| Presque Isle | 181 | 0 | 0 | 1,430 | 1,839 |
| Sandusky | 8,311 | 0 | 1,600 | 150,523 | 193,562 |
| Toledo | 40,611 | 0 | 0 | 188,930 | 242,951 |
| Two Harbors | 104 | 0 | 900 | 8,100 | 10,416 |

TABLE 14E HARBOR DREDGING (continued)

Ship Size = 1300 x 175

| <u>HARBOR</u> | <u>VOLUME</u> | | <u>BREAKWATER</u> | <u>COST</u> | |
|---------------------------|-------------------------|-------------------------|-------------------|-------------|-------------|
| | <u>OVERBURDEN</u> | <u>ROCK</u> | <u>REMOVAL</u> | <u>9/77</u> | <u>1/81</u> |
| | (1000 yd ³) | (1000 ³ yd) | (FT) | (1000 \$) | (1000 \$) |
| <u>SHIP DRAFT = 32 FT</u> | | | | | |
| Ashtabula | 1,624 | 0 | 0 | 20,396 | 26,228 |
| Buffalo | 12,356 | 952 | 0 | 100,452 | 129,174 |
| Burns Harbor | 1,385 | 0 | 0 | 4,050 | 5,208 |
| Calumet | 70,558 | 0 | 0 | 282,230 | 362,928 |
| Cleveland | 4,166 | 0 | 1,300 | 31,057 | 39,937 |
| Conneaut | 1,585 | 0 | 0 | 17,371 | 22,338 |
| Detroit | 5,808 | 0 | 0 | 23,230 | 29,872 |
| Duluth-Superior | 24,640 | 159 | 0 | 174,082 | 223,857 |
| Gary | 523 | 1,267 | 0 | 20,550 | 26,426 |
| Indiana | 6,867 | 0 | 3,800 | 93,400 | 120,106 |
| Lorain | 2,405 | 0 | 1,000 | 49,533 | 63,696 |
| Presque Isle | 748 | 0 | 0 | 7,500 | 9,644 |
| Sandusky | 7,753 | 0 | 1,600 | 231,617 | 297,843 |
| Toledo | 52,861 | 0 | 0 | 292,050 | 375,556 |
| Two Harbors | 316 | 0 | 900 | 19,000 | 24,433 |

SHIP DRAFT = 36 FT

| | | | | | |
|-----------------|---------|-------|-------|---------|---------|
| Ashtabula | 2,412 | 0 | 0 | 42,740 | 54,961 |
| Buffalo | 15,698 | 2,344 | 0 | 215,304 | 276,866 |
| Burns Harbor | 2,200 | 0 | 0 | 6,380 | 8,204 |
| Calumet | 108,275 | 0 | 0 | 433,099 | 556,935 |
| Cleveland | 6,643 | 0 | 0 | 47,872 | 61,560 |
| Conneaut | 2,524 | 0 | 0 | 33,059 | 42,512 |
| Detroit | 7,503 | 0 | 0 | 30,010 | 38,591 |
| Duluth-Superior | 30,360 | 1,428 | 0 | 231,087 | 297,162 |
| Gary | 572 | 2,032 | 0 | 49,280 | 63,371 |
| Indiana | 11,067 | 0 | 3,800 | 205,400 | 264,130 |
| Lorain | 3,399 | 0 | 1,000 | 88,914 | 114,337 |
| Presque Isle | 1,343 | 0 | 0 | 17,100 | 21,989 |
| Sandusky | 13,319 | 0 | 1,600 | 397,884 | 411,651 |
| Toledo | 65,423 | 0 | 0 | 666,380 | 856,918 |
| Two Harbors | 568 | 0 | 900 | 31,900 | 41,021 |

ENR "Construction Cost Index" Sept. 77 = 2644
 Jan. 81 = 3400
 Base: 1913 = 100

TABLE 15 BRIDGE MODIFICATION COSTS (1000\$)

| BRIDGE | SHIP BEAM = 105' | | SHIP BEAM = 130' | | SHIP BEAM = 175' | |
|----------------------------------|------------------|--------|------------------|--------|------------------|--------|
| | 1/77 | 1/81 | 1/77 | 1/81 | 1/77 | 1/81 |
| Duluth-Superior Harbor Bridge | 0 | 0 | 0 | 0 | 4,100 | 5,529 |
| Iroquois Lock Br. | 1,688 | 2,302 | 2,090 | 2,851 | 2,813 | 3,837 |
| Valleyfield Br. | 0 | 0 | 0 | 0 | 3,203 | 4,369 |
| St. Louis Br. | 0 | 0 | 0 | 0 | 3,203 | 4,369 |
| Penn Central RR Br. | 3,400 | 4,638 | 3,676 | 5,014 | 4,090 | 5,579 |
| Beaugharnois RR Br. | 13,600 | 18,550 | 16,900 | 23,052 | 22,800 | 31,099 |
| Cote Ste. Catherine Br. | 1,688 | 2,302 | 2,090 | 2,851 | 2,813 | 3,837 |
| St. Lambert Hwy & RR Br. | 27,000 | 36,828 | 33,800 | 46,103 | 45,500 | 62,062 |
| Jacques Cartier | 0 | 0 | 0 | 0 | 3,000 | 4,092 |

ENR "Building Cost Index" Jan. 77 = 1489
 Jan. 81 = 2031
 Base: 1913 = 100

TABLE 16 TUNNEL MODIFICATION COSTS (1000 \$)

| TUNNEL | BEAM (ft) | DRAFT = 25.5' | | DRAFT = 28' | | DRAFT = 32' | | DRAFT = 36' | |
|------------------|--------------|---------------|--------|-------------|--------|-------------|--------|-------------|--------|
| | | 1/77 | 1/81 | 1/77 | 1/81 | 1/77 | 1/81 | 1/77 | 1/81 |
| Eisenhower Lock | 105 | 19,700 | 26,871 | 21,700 | 29,599 | 24,800 | 33,827 | 27,900 | 38,056 |
| | 130 | 24,400 | 33,282 | 26,800 | 36,555 | 30,700 | 41,875 | 34,500 | 47,058 |
| | 175 | 32,900 | 44,876 | 36,300 | 49,513 | 41,300 | 56,333 | 46,600 | 63,563 |
| Beauharnois Hwy. | 105 | 13,100 | 17,868 | 14,300 | 19,505 | 16,400 | 22,370 | 18,400 | 25,098 |
| | 130 | 16,200 | 22,097 | 17,700 | 24,143 | 20,300 | 27,689 | 22,800 | 31,099 |
| | 175 | 21,800 | 29,735 | 24,100 | 32,872 | 27,300 | 37,237 | 30,900 | 42,148 |

ENR "Building Cost Index" Jan. 77 = 1489
 Jan. 81 = 2031
 Base: 1913 = 100

4.7 Contingency

A contingency estimate of 20% of the sum of the updated federal construction capital costs, aids to navigation cost, and real estate cost was used in the updated cost estimate in the same manner as was used for the original study.

4.8 Engineering and Design, Supervision and Administration

It is estimated that engineering and design will cost 5% of the updated total federal capital costs, which are the federal construction capital costs plus the aids to navigation costs, the real estate cost, and the contingency allowance. Supervision and administration costs are estimated to be 6% of the updated federal capital costs plus the engineering and design costs. These methods are identical to those used in the original study.

4.9 Non-Federal First Costs

Non-federal first costs include the costs of items such as pipeline and cable relocation. They do not include the costs of docks, piers, and cargo handling equipment. Non-federal first costs are estimated to be 2% of the federal first costs, which are the federal capital costs plus the engineering and design cost, and the supervision and administration cost as was done in the original study.

4.10 Investment Costs

Investment cost is the foregone interest earnings on the federal funds used during the construction period, prior to the start of benefits. A five year period from the start of construction to the first accrual of benefits was assumed for the "Maximum Ship Size Study". The specified interest rate for Fiscal Year 1981, which extends from October 1, 1980 through September 30, 1981, is 7.375%. The capital investment is the total first cost, consisting of the sum of the non-federal first costs and the federal first costs.

4.11 Operation and Maintenance Costs

The operation and maintenance costs given in the "Maximum Ship Size Study" were estimated increases in maintenance dredging costs for the GL/SLS System resulting from the proposed System improvements. Increased maintenance dredging would be expected in the harbors because of the additional area which must be kept open

due to the modifications. These costs were based on a four year average of maintenance dredging costs, which were obtained from Corps of Engineers Annual Reports, and were updated to October 1977 dollars using an *Engineering News Record* cost index. Only the maintenance dredging cost was included in the increase of operation and maintenance costs in the "Maximum Ship Size Study" because it would be by far the largest cost increase.

The operation and maintenance costs were updated in this report from October 1977 dollars to January 1981 dollars by applying the *Engineering News Record* "Construction Cost Index". The original and updated operation and maintenance costs are summarized in Tables 17A through E.

TABLE 17A MAINTENANCE DREDGING COSTS
SHIP SIZE = 940 x 105

| HARBOR | VOL (1000 yd ³) | DRAFT = 25.5 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | DRAFT = 28 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | DRAFT = 32 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | DRAFT = 36 9/77 (1000\$) | 1/81 (1000\$) |
|-----------------|--------------------------------|-------------------------------|------------------|--------------------------------|-----------------------------|------------------|--------------------------------|-----------------------------|------------------|--------------------------------|-----------------------------|------------------|
| Ashtabula | | | | | | | | | | | | |
| Buffalo | 10.0 | 48.0 | 61.7 | 11.0 | 53.0 | 68.2 | No Plan | 12.1 | 58.0 | 74.6 | No Plan | No Plan |
| Burns | 0 | 0 | 0 | 0 | 0 | 0 | No Plan | 0 | 0 | 0 | No Plan | No Plan |
| Calumet | | | | | | | | | | | | |
| Cleveland | 6.1 | 10.0 | 12.9 | 6.1 | 10.0 | 12.9 | No Plan | 7.9 | 13.0 | 16.7 | No Plan | No Plan |
| Conneaut | | | | | | | | | | | | |
| Detroit | 73.1 | 20.0 | 25.7 | 120.7 | 33.0 | 42.7 | No Plan | 131.7 | 36.0 | 46.3 | No Plan | No Plan |
| Duluth/Superior | 0 | 0 | 0 | 4.2 | 20.0 | 25.7 | No Plan | 6.3 | 30.0 | 38.6 | No Plan | No Plan |
| Gary | 0 | 0 | 0 | 0 | 0 | 0 | No Plan | 0 | 0 | 0 | No Plan | No Plan |
| Indiana | | | | | | | | | | | | |
| Lorain | | | | | | | | | | | | |
| Milwaukee | 0 | 0 | 0 | 2.9 | 19.0 | 24.4 | No Plan | 3.8 | 25.0 | 32.1 | No Plan | No Plan |
| Presque Isle | 0 | 0 | 0 | 0 | 0 | 0 | No Plan | 0 | 0 | 0 | No Plan | No Plan |
| Sandusky | | | | | | | | | | | | |
| Toledo | 80.0 | 183.0 | 235.3 | 87.9 | 201.0 | 259.0 | No Plan | 96.6 | 221.0 | 284.2 | No Plan | No Plan |
| Two Harbors | 0 | 0 | 0 | 0 | 0 | 0 | No Plan | 0 | 0 | 0 | No Plan | No Plan |

ENR "Construction Cost Index" Sept. 77 = 2644
Jan. 81 = 3400
Base: 1913 = 100

TABLE 17B MAINTENANCE DREDGING COSTS
SHIP SIZE = 1100 x 105

| HARBOR | DRAFT = 25.5 | | DRAFT = 28 | | DRAFT = 32 | | DRAFT = 36 | | | |
|-----------------|--------------------------------|-------------------------|-------------------------|--------------------------------|-------------------------|-------------------------|--------------------------------|-------------------------|-------------------------|---------|
| | VOL (1000 yd ³) | <u>9/77</u> (1000\$) | <u>1/81</u> (1000\$) | VOL (1000 yd ³) | <u>9/77</u> (1000\$) | <u>1/81</u> (1000\$) | VOL (1000 yd ³) | <u>9/77</u> (1000\$) | <u>1/81</u> (1000\$) | |
| Ashtabula | 15.4 | 10.0 | 12.9 | 21.6 | 14.0 | 18.0 | 46.2 | 30.0 | 38.6 | No Plan |
| Buffalo | 10.0 | 48.0 | 61.7 | 11.0 | 53.0 | 68.2 | 12.1 | 58.0 | 74.6 | No Plan |
| Burns | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Plan |
| Calumet | 1.1 | 4.0 | 5.1 | 1.6 | 6.0 | 7.7 | 2.1 | 8.0 | 10.3 | No Plan |
| Cleveland | 6.1 | 10.0 | 12.9 | 6.1 | 10.0 | 12.9 | 7.9 | 13.0 | 16.7 | No Plan |
| Conneaut | 0 | 0 | 0 | 0 | 0 | 0 | 8.5 | 10.0 | 12.9 | No Plan |
| Detroit | 73.1 | 20.0 | 25.7 | 120.7 | 33.0 | 42.7 | 131.7 | 36.0 | 46.3 | No Plan |
| Duluth/Superior | 8.4 | 40.0 | 51.4 | 10.3 | 49.0 | 63.0 | 12.4 | 59.0 | 75.9 | No Plan |
| Gary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Plan |
| Indiana | 0.8 | 2.0 | 2.6 | 1.5 | 4.0 | 5.1 | 2.3 | 6.0 | 7.7 | No Plan |
| Lorain | 0 | 0 | 0 | 4.7 | 8.0 | 10.3 | 11.8 | 20.0 | 25.7 | No Plan |
| Milwaukee | | | | No Plan | | | | | | |
| Presque Isle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Plan |
| Sandusky | 11.0 | 10.0 | 12.9 | 37.5 | 34.0 | 43.7 | 45.2 | 41.0 | 52.7 | No Plan |
| Toledo | 80.0 | 183.0 | 235.3 | 87.9 | 201.0 | 259.0 | 96.6 | 221.0 | 284.2 | No Plan |
| Two Harbors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Plan |

ENR "Construction Cost Index" Sept. 77 = 2644
Jan. 81 = 3400
Base: 1913 = 100

TABLE 17C MAINTENANCE DREDGING COSTS
SHIP SIZE = 1200 x 130

| HARBOR | DRAFT = 25.5 | | DRAFT = 28 | | DRAFT = 32 | | DRAFT = 36 | |
|-----------------|-------------------------|----------|-------------------------|----------|-------------------------|----------|-------------------------|----------|
| | VOL | 1/81 | VOL | 1/81 | VOL | 1/81 | VOL | 1/81 |
| | (1000 yd ³) | (1000\$) | (1000 yd ³) | (1000\$) | (1000 yd ³) | (1000\$) | (1000 yd ³) | (1000\$) |
| Ashtabula | 18.5 | 12.0 | 15.4 | 18.0 | 61.6 | 40.0 | 92.5 | 60.0 |
| Buffalo | 12.3 | 59.0 | 75.9 | 84.9 | 15.2 | 73.0 | 16.6 | 80.0 |
| Burns | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calumet | 1.1 | 4.0 | 5.1 | 7.7 | 2.1 | 8.0 | 2.6 | 10.0 |
| Cleveland | 8.5 | 14.0 | 18.0 | 20.6 | 18.2 | 30.0 | 30.4 | 50.0 |
| Conneaut | 8.5 | 10.0 | 12.9 | 15.4 | 12.7 | 15.0 | 25.5 | 30.0 |
| Detroit | 91.4 | 25.0 | 32.1 | 52.7 | 164.6 | 45.0 | 179.2 | 49.0 |
| Duluth/Superior | 11.6 | 55.0 | 70.7 | 83.6 | 16.4 | 78.0 | 19.8 | 94.0 |
| Gary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indiana | 0.8 | 2.0 | 2.6 | 5.1 | 2.3 | 6.0 | 3.0 | 8.0 |
| Lorain | 2.4 | 4.0 | 5.1 | 15.4 | 13.0 | 22.0 | 23.7 | 40.0 |
| Milwaukee | | | | No Plan | | | | |
| Presque Isle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandusky | 33.1 | 30.0 | 38.6 | 56.6 | 58.5 | 53.0 | 76.1 | 69.0 |
| Toledo | 781.0 | 842.0 | 1,083.0 | 1,191.0 | 944.0 | 1,018.0 | 1,039.0 | 1,120.0 |
| Two Harbors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

ENR "Construction Cost Index" Sept. 77 = 2644
Jan. 81 = 3400
Base: 1913 = 100

TABLE 17D MAINTENANCE DREDGING COSTS
SHIP SIZE = 1300 x 130

| HARBOR | DRAFT = 25.5 | | DRAFT = 28 | | DRAFT = 32 | | DRAFT = 36 | | |
|-----------------|--------------------------------|------------------|------------------|--------------------------------|------------------|------------------|--------------------------------|------------------|------------------|
| | VOL (1000 yd ³) | 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | 9/77 (1000\$) | 1/81 (1000\$) |
| Ashtabula | 18.5 | 12.0 | 15.4 | 27.7 | 18.0 | 23.1 | 61.6 | 40.0 | 51.4 |
| Buffalo | 12.3 | 59.0 | 75.9 | 13.7 | 66.0 | 84.9 | 15.2 | 73.0 | 93.9 |
| Burns | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calumet | 1.1 | 4.0 | 5.1 | 1.6 | 6.0 | 7.7 | 2.1 | 8.0 | 10.3 |
| Cleveland | 8.5 | 14.0 | 18.0 | 9.7 | 16.0 | 20.6 | 18.2 | 30.0 | 38.6 |
| Conneaut | 8.5 | 10.0 | 12.9 | 10.2 | 12.0 | 15.4 | 12.7 | 15.0 | 19.3 |
| Detroit | 109.7 | 30.0 | 38.6 | 179.2 | 49.0 | 63.0 | 197.5 | 54.0 | 69.4 |
| Duluth/Superior | 13.7 | 65.0 | 83.6 | 15.6 | 74.0 | 95.2 | 18.7 | 89.0 | 114.4 |
| Gary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indiana | | 2.0 | 2.6 | 1.5 | 4.0 | 5.1 | 2.3 | 6.0 | 7.7 |
| Lorain | 3.7 | 6.0 | 7.7 | 7.1 | 12.0 | 15.4 | 15.4 | 26.0 | 33.4 |
| Milwaukee | | | | No Plan | | | | | |
| Presque Isle | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandusky | 41.7 | 38.0 | 48.9 | 53.0 | 48.0 | 61.7 | 64.0 | 58.0 | 74.6 |
| Toledo | 781.0 | 842.0 | 1,083.0 | 859.0 | 926.0 | 1,191.0 | 944.0 | 1,018.0 | 1,309.0 |
| Two Harbors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

ENR "Construction Cost Index" Sept. 77 = 2644
Jan. 81 = 3400
Base: 1913 = 100

TABLE 17E MAINTENANCE DREDGING COSTS
SHIP SIZE = 1300 x 175

| HARBOR | DRAFT = 25.5 | | | DRAFT = 28 | | | DRAFT = 32 | | | DRAFT = 36 | | |
|-----------------|--------------------------------|------------------|------------------|--------------------------------|------------------|------------------|--------------------------------|------------------|------------------|--------------------------------|------------------|------------------|
| | VOL (1000 yd ³) | 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | 9/77 (1000\$) | 1/81 (1000\$) | VOL (1000 yd ³) | 9/77 (1000\$) | 1/81 (1000\$) |
| Ashtabula | 21.6 | 14.0 | 18.0 | 37.0 | 24.0 | 30.9 | 84.8 | 55.0 | 70.7 | 131.0 | 85.0 | 109.3 |
| Buffalo | 16.6 | 80.0 | 102.9 | 18.5 | 89.0 | 114.4 | 20.4 | 98.0 | 126.0 | 22.2 | 107.0 | 137.6 |
| Burns | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Calumet | 1.1 | 4.0 | 5.1 | 1.6 | 6.0 | 7.7 | 2.1 | 8.0 | 10.3 | 2.6 | 10.0 | 12.9 |
| Cleveland | 10.9 | 18.0 | 23.1 | 12.1 | 20.0 | 25.7 | 24.3 | 40.0 | 51.4 | 48.6 | 80.0 | 102.9 |
| Conneaut | 11.0 | 13.0 | 16.7 | 11.9 | 14.0 | 18.0 | 17.0 | 20.0 | 25.7 | 29.7 | 35.0 | 45.0 |
| Detroit | 146.3 | 40.0 | 51.4 | 237.7 | 65.0 | 83.6 | 263.3 | 72.0 | 92.6 | 288.9 | 79.0 | 101.6 |
| Duluth/Superior | 16.8 | 80.0 | 102.9 | 20.6 | 98.0 | 126.0 | 24.8 | 118.0 | 151.7 | 29.8 | 142.0 | 182.6 |
| Gary | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indiana | 0.8 | 2.0 | 2.6 | 1.5 | 4.0 | 5.1 | 2.3 | 6.0 | 7.7 | 3.0 | 8.0 | 10.3 |
| Lorain | 4.7 | 8.0 | 10.3 | 8.9 | 15.0 | 19.3 | 17.8 | 30.0 | 38.6 | 29.6 | 50.0 | 64.3 |
| Milwaukee | | | | No Plan | | | | | | | | |
| Presque Isle | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sandusky | 46.3 | 42.0 | 54.0 | 57.4 | 52.0 | 66.9 | 68.4 | 62.0 | 79.7 | 81.6 | 74.0 | 95.2 |
| Toledo | 1,328.0 | 1,432.0 | 1,841.0 | 1,461.0 | 1,575.0 | 2,025.0 | 1,607.0 | 1,733.0 | 2,229.0 | 1,768.0 | 1,906.0 | 2,451.0 |
| Two Harbors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

ENR "Construction Cost Index" Sept. 77 = 2644
Jan. 81 = 3400
Base: 1913 = 100

5. RECOMMENDATIONS

This subtask has itemized the cost information from the draft "Maximum Ship Size Study" and has updated those costs to January 1981 dollars. In doing this, it has been assumed that the cargo forecasts made for use in the study are still reasonable. New cargo forecasts are being made by Booz, Allen and Hamilton under another task of this Great Lakes/St. Lawrence Seaway Regional Transportation Study. While updating the cargo forecasts will not change the costs documented in this report, they could affect the optimal ship selection which was made in the original "Maximum Ship Size Study."

ARCTEC, Incorporated is currently developing a new fleet mix model to predict the future Great Lakes/St. Lawrence Seaway fleet mix based on projected cargo demands. This fleet mix model could also be used to refine the "Maximum Ship Size Study", replacing the Study's fleet mix model which simply assumes that all new ships are of maximum size.

Finally, the entire Study could be refined by reevaluating the underlying assumptions of the study in view of current national and world conditions. Appendix A of the original "Maximum Ship Size Study" stated the assumption that all ships will be U.S. constructed and U.S. manned [1]. Obviously such assumptions do not take the current world fleet into account. The only benefits taken into account are those which would accrue to the United States. Clearly Canada has a considerable interest in the GL/SLS System and could also derive significant benefits from System improvements. The draft "Maximum Ship Size Study" estimated that the Canadian share of the improvement costs could be 25%. A revised study could examine both the Canadian and U.S. interests in greater detail and better estimate a cost sharing methodology. All of these additional considerations could have significant impact on the optimum vessel size.

6. REFERENCES

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